Original Research

Effects of Carbohydrate-Protein Ingestion Post-Resistance Training in Male Rugby Players

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ABSTRACT

Int J Exerc Sci 5(1) : 39-49, 2012. Evidence suggests that carbohydrate-protein (CHO-PRO) drinks post-exercise are an advantageous nutritional recovery intervention. Resistance trained (n = 14, mean ± SD; age 19 ± 1 yr, mass 95 ± 9 kg, % fat 17 ± 4 % and BMI 28.5 ± 1.8 $kg.m^{-2}$) male rugby players participated in a study investigating effects of carbohydrate (CHO) and CHO-PRO drinks on subsequent resistance exercise performance. Following an initial resistance training (RT) protocol consisting of 8 circuits of 5 discrete exercises at 10 repetition maximum (RM), participants received 10 $mL.kg^{-1}$ BM of randomised sports drink (LCHO, HCHO and CHO-PRO) on completion of the RT protocol and at 120 min into a 240 min recovery period. Post-recovery, participants completed a test to failure (TTF) protocol performing as many circuits of the same exercises at 10-RM to failure. Individual exercise cumulative load (ΣW) lifted and total work capacity (TWC) for each trial was recorded. Both ΣW and TWC were normalised for body mass ($kg.kg^{-1}$ BM). Data were analysed using repeated measures ANOVA with post-hoc Student-Neuman-Keuls pair-wise comparisons ($P<0.05$). Despite large intra-subject variability between trials, TWC normalised for body mass was significantly greater following CHO-PRO compared with HCHO and LCHO (188 ± 26 vs. 157 ± 21 and 150 ± 16 $kg.kg^{-1}$ BM, respectively; $P<0.05$). The ΣW lifted after ingestion of HCHO and LCHO were not significantly different despite differing CHO and caloric content. The CHO-PRO induced enhancement of recovery was possibly due to higher rates of glycogen restoration after the initial glycogen depleting RT protocol.

KEY WORDS: Carbohydrate-protein, resistance training, recovery

INTRODUCTION

Glycogen is a primary fuel for rugby union performance and, along with maintaining a positive protein (PRO) balance, restoration of muscle glycogen is essential for sustained rugby union performance (7, 19). Despite the wide variety of recovery modalities available, restoration of capacity by replenishing utilised glycogen and rehydration between training sessions remains a primary objective (12, 17). The varying skill set required by rugby players coupled with the intense nature of the game (7, 20) present challenges in achieving a balance between training and competition stresses and recovery. Resistance training (RT) forms an integral part of rugby players' training (1) and a milieu of hormonal responses critical to acute

muscular force and power production, as well as subsequent tissue growth and remodelling, are elicited by resistance training (15). Maximising recovery by rehydration (23), liver and muscle glycogen restoration (12, 17) and minimising disturbances to the immune system post-training by sports drinks supplementation (16, 20) reduces the necessity for extended rest periods after high load training.

Achieving the balance between training and competition stresses and recovery is important in maximising the performance of athletes (2). Evidence suggests that ingestion of carbohydrate-protein (CHO-PRO) drinks post-exercise would be an advantageous nutritional recovery intervention (3, 4, 8, 9, 31, 33). Ingestion of CHO-PRO drinks post-exercise results in significantly higher muscle glycogen replenishment (3, 9) and, furthermore, limited evidence suggests significantly enhanced exercise performance (4) when compared with iso-caloric and equivalent carbohydrate (CHO) drinks. These responses have been attributed to an insulinotropic effect (30, 31) with better glucose availability potentially responsible for enhanced post-recovery performance (4). Protein and certain amino acids (AA) were effective stimulators of insulin secretion and synergistically increased the blood insulin responses when combined with a CHO supplement (11, 24, 30, 31, 33, 34). This greater rate of glycogen restocking was thought to be the result of a greater plasma insulin response brought about by the addition of PRO to a CHO supplement (24).

A CHO intake of approximately 1.2 $g.kg^{-1}.h^{-1}$ commencing immediately upon completion of strenuous exercise and continuing at regular intervals is recommended (10). Recommended PRO intake for strength or speed athletes ranges between 1.2 and 1.7 $g.kg^{-1}$ $BM.day^{-1}$ (25). The greatest stimulation of PRO synthesis results from resistance exercise plus AA availability (21). Exogenous AA facilitate PRO synthesis and decrease the impact of the post-exercise catabolic environment (21).

Previous research into an ergogenic advantage of a CHO-PRO beverage on RT performance failed to produce conclusive results (6). However, a possible, but inconclusive, ergogenic benefit of addition of PRO to CHO may exist (4) occurring via an interaction of ingested AA with the CNS (18). An effect of addition of PRO to CHO on the central fatigue hypothesis was previously postulated (10). Research evaluating co-ingestion of PRO with CHO has produced varying results; addition of approximately 0.15 g PRO.kg $BM^{-1}.h^{-1}$ to a CHO supplement enhanced performance (19, 23), however, a higher dose (0.26 g PRO.kg $BM^{-1}.h^{-1}$) did not (28).

Many studies have suggested that the addition of PRO to a CHO supplement can be used as a nutritional supplement in order to increase glycogen resynthesis post-exercise, subsequently improving recovery and quickening return to optimum performance (9, 30, 31). The increased rates of glycogen resynthesis post-supplementation have been attributed to an insulinotropic effect (30, 31). In view of the conflicting findings in previous research the present study proposed to evaluate if a CHO-PRO supplement, by potentially inducing a greater degree of glycogen

restocking compared to iso-carbohydrate or iso-caloric equivalents, would significantly increase time to failure during the RT regimen performed 240 min after a standard RT protocol in male resistance trained athletes.

We hypothesised that CHO-PRO supplementation would significantly increase time to failure and normalised cumulative workload (ΣW; $kg.kg^{-1}$ BM) during the RT regimen performed 240 min following a standard RT protocol designed to induce glycogen depletion when compared with supplements of equivalent CHO (LCHO) and caloric content (HCHO).

METHODS

Participants

Eighteen (n=18) male resistance trained members of the Leinster Rugby Development Academy were recruited as participants. They had been playing club or provincial schools rugby during the previous season and most had provincial and underage (junior) representative honours. Each participant was informed of the potential risks and procedures associated with the study and they provided written consent prior to testing. Participants underwent medical screening prior to their first testing session; those suffering from minor sporting injuries such as sprains, muscle stiffness or bruising were allowed to participate and performed exercises within the limits of their injuries. Participants presenting with any musculoskeletal injury that had prevented participation in training within the last month, diabetes, hypertension, heart defects, metabolic disorders, chronic sports injury, epilepsy or deemed unfit to participate due to influenza or respiratory tract infection were excluded. All testing took place during the pre-season training cycle and the study protocol was approved by the Faculty of Health Sciences research ethics committee, Trinity College Dublin.

Table 1. Physical characteristics of participant academy rugby union players.

n = 14	Age (yr)	Body mass (kg)	Height (m)	BMI ($kg.m^2$)	Body fat (%)
Mean	19	94.8	1.82	28.5	17.1
SD	1	9.1	0.07	1.8	4.3

Mean (±SD) physical characteristics of participants.

Experimental design

The protocol involved a single-blinded, repeated measures design and participants visited the gymnasium on four separate occasions. During their initial visit, 7 days prior to their first scheduled drinks trial, each individual's 3 repetition maximum (3-RM) for discrete resistance exercises was determined. Height and body mass (BM) were assessed using an electronic scale (Salter, Tonbridge, UK) and a standard tape measure (Stanley, Sheffield, UK) secured to a flat surface. Percentage body fat was estimated from skinfold thickness at triceps, bicep, subscapular and suprailiac using a skinfold caliper (Baty International, West Sussex, UK). During subsequent visits, 3 to 4 days apart, participants completed the following protocol; a standard resistance training (RT) phase (120 min), a recovery period (240 min) and a test to failure phase (TTF). During the 240 min recovery period, participants were randomised to consume each of the three sports drinks under investigation.

Experimental Protocol

Participants presented themselves at the gymnasium in a rested, well-hydrated state. Pre-test fluid intake, diet and training were standardised in the 24 h prior to each trial to limit extrinsic effects on results. Participant's body mass was recorded and they were provided with a standardised breakfast providing 10 g CHO.kg^{-1} BM for consumption no less than 60 min prior to commencing exercise. Subsequently they performed their initial RT exercise protocol and received 1 mL.kg^{-1} BM of water at 15 min intervals throughout this exercise period. During the 240 min recovery period, participants received two separate boluses of assigned sports drink. Participants remained at rest during the recovery period and began their TTF exercise protocol at the end of this recovery / sports drink ingestion period.

Resistance Training Protocol

Participants began the RT phase following a supervised dynamic warm-up which included exercises such as shoulder 'dislocates', press-ups, un-weighted standing shoulder press, back squat and lunge. The RT protocol consisted of 8 circuits of 5 discrete exercises, namely arm curls (York; Daventry, UK), squat (York; Daventry, UK), bench press (T-Rex Multisystem, Beijing, China), leg press (Jimsa; Istanbul, Turkey) and hamstring curls (Techno Gym; Gambettola, Italy). These exercises were chosen as they were performed as part of the participant's regular strength and conditioning. The prescribed load for the resistance exercises was 10-RM. Participants exercised in pairs due to scheduling and equipment constraints but also for safety. Each pair had 120-s to complete the required number of repetitions at each exercise station. Exercise and rest durations varied according to the exercise involved but never exceeded 90-s, therefore, if an individual took 45-s to perform the required number of repetitions of a given exercise, the rest interval was 75-s. This RT phase lasted for approximately 80 min.

Test to failure (TTF) performance test

During the TTF phase participants performed as many circuits of the same 5 exercises at 10-RM to failure. Failure was defined as the inability to complete the required number of repetitions during any three exercises within one RT circuit and consequently, the duration of the TTF phase varied according to each individual's post-recovery capacity. The sequence of exercise performance was the same as during the initial RT phase and each pair had 120-s to complete the allotted number of repetitions for each exercise. Water was available for participants to drink *ad-libitum*. Individual exercise ΣW and total work capacity (TWC) for each drink trial were recorded. Data for ΣW and TWC were normalised for body mass and expressed in kg.kg^{-1} BM.

Sports drinks

Participants received 10 mL.kg^{-1} BM bolus of sports drink within 10 min of cessation of the RT phase and again at 120 min into the recovery period and all drinks were consumed within 10 min. LCHO was a commercially available sports drink (Club Energise Sport, Britvic, Ireland) providing 6.2g CHO.100 mL^{-1}; HCHO consisted of the sports drink with added glucose providing 9.3g CHO.100 mL^{-1}; CHO-PRO consisted of a commercially available CHO-PRO sports drink (Club Energise Sport Recovery 20, Britvic, Ireland) providing 6.2g CHO.100

mL^{-1} and 3.1g PRO.100 mL^{-1}. Both HCHO and CHO-PRO were volumetrically and iso-calorically equivalent while LCHO and CHO-PRO were equivalent for volume and CHO content.

Statistical analysis

Normalised ΣW for individual exercises and TWC across trial arm were analysed using a single factor, repeated measures ANOVA with significance quantified using *post-hoc* Student-Neuman-Keuls pair-wise comparisons (InStat, GraphPad Prism, La Jolla, USA). The α level to infer statistical significance was set at $P < 0.05$.

RESULTS

Participants

Fourteen participants completed all 3 drinks trials and their TTF performance data were included in analysis. The other 4 participants were forced to withdraw due to injury, attrition and unscheduled club commitments. Physical characteristics for study participants (n=14) are presented as mean ± standard deviation (SD) while all performance data are presented as mean ± standard error of the mean (SEM). Players' physical characteristics are presented in Table 1.

Total Work Capacity

Despite large intra-subject variability between trials, TWC, when normalised for body mass ($kg.kg^{-1}$ BM), was significantly greater following CHO-PRO ingestion when compared with HCHO and LCHO ($P<0.05$). The greatest mean TWC was recorded post-ingestion of CHO-PRO, with decreasing TWC recorded following HCHO and LCHO supplementation, see Figure 1 (188 ± 26 vs. 157 ± 21 and 150 ± 16 $kg.kg^{-1}$ BM, respectively). Mean TWC following ingestion of HCHO and LCHO drinks were not significantly different despite their differing CHO and caloric contents.

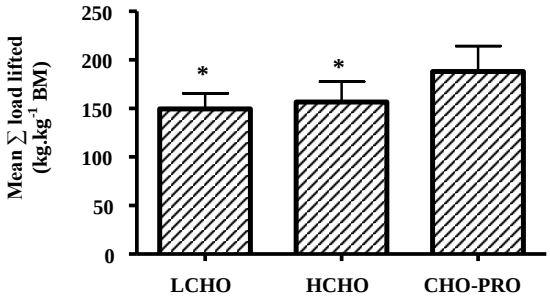

Figure 1. Mean (±SEM) cumulative load lifted ($kg.kg^{-1}$ BM) during TTF across drinks, n=14. * infers that HCHO and LCHO were significantly lower than CHO-PRO at $P<0.05$.

Individual exercise performance data

Individual exercise performance varied greatly from subject-to-subject and also following each drink trial. Mean ΣW normalised data from four out of the five exercises performed demonstrated the trend that the ΣW was greatest following ingestion of HCHO and CHO-PRO when compared with LCHO; leg curl was the exception, see Table 2. Mean ΣW following CHO-PRO ingestion was significantly greater ($P<0.05$) than HCHO and LCHO for squat and leg curl, no significant differences were detected across drinks trials for bench press or leg press, and following CHO-PRO mean ΣW for biceps curl was significantly greater ($P<0.05$) only in comparison with LCHO.

DISCUSSION

We hypothesised that ingestion of a CHO-PRO supplement would induce a greater

degree of glycogen regeneration, therefore increasing TTF, when compared with a simple CHO supplement or an iso-caloric equivalent. However, several factors must be considered regarding exercise to failure, with substrate availability just one component of the intricate physiological response.

Benefits of CHO-electrolyte and CHO-PRO drinks on restoration of glycogen after intermittent or endurance exercise (3, 9, 30) and subsequent performance (4) have previously been reported. Various ratios of CHO:PRO have been evaluated, from 2:1 (3, 30), 3:1 (4, 9) and upwards of 4:1 (32), the current study used a ratio of 2:1. Kerksick *et al.* (14) stated that CHO and PRO ingested at a ratio of 3:1 promoted recovery and replenished muscle glycogen stores, regardless of timing, when ingested regularly. The addition of PRO and AA mixtures to CHO induces an insulinotropic response (30, 31, 33) with the available glucose being easily absorbed by the tissue during the recovery period.

In this study, despite large intra-subject variability between trials, mean TWC was significantly greater following CHO-PRO compared with HCHO or LCHO, see Figure 1, this observation is in agreement with previous research (4). In addition, differences in TWC after ingestion of HCHO or LCHO were not detected. At first glance, the current results merit the conclusion that post-exercise CHO-PRO ingestion enhanced recovery and resulted in greater work capacity when compared with HCHO and LCHO. The lack of significant differences between HCHO and LCHO suggest that CHO and caloric differences were not contributory factors, implying that the PRO component of the CHO-PRO supplement was responsible for the enhanced performance capacity. Previous research reporting differences in exercise capacity between LCHO and HCHO concluded that any bias towards a CHO-PRO mixture in terms of CHO content would be expected to prolong exercise capacity irrespective of the additional PRO (4). However, these results are also indicative that CHO-PRO may be more effective for the restoration of muscle glycogen than CHO alone and are broadly in line with data previously reported (3, 4, 9, 30, 31).

Individual exercise data provided an insight into the similarity between mean ΣW lifted after HCHO and LCHO. Mean ΣW lifted after ingestion of CHO-PRO was significantly higher in 3 of the 5 exercises compared with LCHO (see Table 2); no significant differences were detected comparing HCHO and LCHO. One possible explanation for the differing workloads in individual exercises, in particular that observed for leg curl, is the difference in muscle mass of players due to their playing position specificity. Study participants consisted of 9 forwards and 5 backs with power, strength and endurance in horizontal pushing/wrestling activities reported to be important requisites for forwards and fast running an important requisite for backs (19).

Greater glycogen restoration after ingestion of a combined CHO-PRO supplement has been attributed to the greater plasma insulin response (10, 30, 33) with the subsequent rise in insulin supposedly accelerating glucose disposal, and a possible increase in glycogen synthase

activity accelerating glycogen synthesis (12). Studies report similar insulin responses across supplements with varying blood glucose responses (8, 9, 33). Despite a reported similarity in insulin response across drinks, Ivy *et al*. (9) observed significantly lower glucose concentrations for the first 180 min of their monitored 240 min recovery period and for all time points except at 120 min following ingestion of HCHO and LCHO when compared with CHO-PRO. A 92% greater insulin response accompanied the reported 128% greater storage of muscle glycogen after CHO-PRO ingestion compared with a non-calorically matched CHO-electrolyte sports drink (32). In addition, the insulin response was similar across drink trials except during the recovery period where the insulin response after CHO-PRO ingestion was significantly higher when compared with CHO ingestion (4).

Ivy *et al*. (9) could not attribute increased glycogen restocking during CHO-PRO treatment to a greater plasma insulin response, or differences in circulating plasma catecholamines or NEFA. They theorised that the lower plasma glucose and lactate concentrations detected during recovery post CHO-PRO supplementation possibly indicated increased uptake of plasma glucose and a redistribution of intracellular glucose disposal by the addition of PRO to a CHO supplement. Higher insulin concentrations do not necessarily translate into a higher muscle glycogen resynthesis rate, especially when large volumes of CHO are ingested (10) and currently not all researchers agree that increasing CHO intake during recovery will facilitate restoration of exercise capacity (27). No further enhancement of glycogen resynthesis was recorded during recovery when PRO or additional CHO was added to a feeding strategy providing 1.2 g $CHO.kg^{-1}.h^{-1}$ (7). Ingestion of a large amount of CHO (175 *vs*. 50 g) at frequent intervals during recovery from exercise resulted in greater glycogen restoration during recovery but did not affect the rate of muscle glycogen utilization during subsequent exercise (27). While supplementation in the present study was infrequent by comparison with previous research (4, 27), it is possible that this was the mechanism by which HCHO augmented an ergogenic effect over LCHO in previously reported research (4).

Previously, improved endurance performance during CHO-PRO supplementation was speculated to be due to PRO providing precursors for anaplerotic reactions required to maintain tricarboxylic acid cycle intermediaries in skeletal muscle (10). Elevated concentrations of plasma urea observed during TTF after CHO-PRO ingestion could indicate increased availability of α-keto acids for gluconeogenesis (4). Another possible explanation for the blood glucose response after ingestion of CHO-PRO *vs*. LCHO is that gastric emptying may have been delayed due to the additional energy in the form of PRO (4) and/or intestinal uptake rate of CHO-PRO mixtures (13) leading to exogenous CHO still appearing in the circulation at the start of the TTF (4).

Substrate availability has been suggested as a rate-limiting factor for glycogen restocking (30). In this study, mean TWC was not significantly different between CHO-PRO and HCHO, similar to findings reported in endurance running times (4).

However, the insulinotropic response from the addition of PRO to CHO is not immune to the upper limit of glucose absorption, approximately 1 $g.min^{-1}$, through sodium dependant glucose transporters. Previous research (12) suggested that maximal glycogen restocking rates occurred at a CHO intake of approximately 1.2$g.kg^{-1}.h^{-1}$ and it has also been suggested that intestinal absorption of glucose may be a limiting factor for exogenous CHO oxidation. Drinks in this study were administered according to individual body mass, therefore, an individual weighing 100 kg received 700mL of test drink, providing 0.62 g CHO.kg $BM^{-1}.h^{-1}$ for LCHO and CHO-PRO, increasing to 0.93 g CHO.kg $BM^{-1}.h^{-1}$ for HCHO.

Another factor of importance relating to glycogen resynthesis is the level of depleted glycogen. Following relatively low levels of glycogen depletion (30 to 35 $mmol.L^{-1}$) CHO feedings alone may be sufficient to stimulate maximal resynthesis rates due to the insulin independence to glycogen resynthesis and the high physiological drive to re-synthesise utilised muscle glycogen (3). The insulinotropic effects of combined CHO-PRO ingestion may be better suited where glycogen depletion is greater than 30 $mmol.L^{-1}$ (3). In the current study, glycogen depletion during the initial RT phase was not assessed. As participants regularly performed high-volume training throughout the year, it is plausible to assume that following the RT protocol glycogen depletion may have been of insufficient magnitude to manifest a significant restoration or enhancement of work capacity after ingestion of CHO-PRO. Another possibility is that central fatigue resulted in a reduction in motor unit recruitment potentially affecting the participant's ability to continue lifting the required loads.

Considering previous research, a CHO-PRO supplement can increase the rate of muscle glycogen storage post-exercise if the supplement contains a low to moderate amount of CHO (9, 30, 33) and will also restore exercise capacity more completely within 4 h of prior exercise (4). Previous research (3) supplemented 1 L boluses at 10, 60 and 120 min during recovery with one solid meal (7 $kcal.kg^{-1}$ containing 1.2 $g.kg^{-1}$ CHO, 0.3 $g.kg^{-1}$ PRO and 0.1 $g.kg^{-1}$ fat) ingested at 240 min. Alternatively, a more recent study (4) provided 8 boluses of test drink every 30 min over a 240 min recovery/supplementation period, with blood samples collected hourly. In addition, exercise intensity varied across studies assessing any performance component of enhanced recovery (3, 4). Previously researchers (3) have examined a 60 minute 'best-effort' cycling bout before and after a 5 h recovery-supplementation period, while others (4) have performed an initial 90 min run at 70% VO_2max, a 240 min recovery/supplementation period and a subsequent TTF assessment at 70% VO_2max. Berardi *et al*. (3) conceded that the glycogen depletion protocol employed in their study was less severe than that utilised in other studies, an important observation as the level of muscle glycogen depletion determines the rate of resynthesis.

The findings of the present study conflict with studies reporting no effect of PRO supplementation on glycogen restocking following exercise (30) or from the addition of PRO to a CHO supplement (29). An

earlier study (27) did not use a control beverage and it was argued that their results were attributable to the supplements caloric imbalance. Muscle glycogen restoration was un-altered with CHO-PRO feeding, provided adequate CHO was provided, and the addition of PRO or AA to their HCHO did not elicit a synergistic insulin response (5). Most recently, researchers did not counterbalance drinks for CHO possibly contributing to the 55% greater time to exhaustion after CHO-PRO ingestion (32).

Differing study design such as the lower PRO concentrations administered and the frequency of supplementation could account for the negative findings reported (5). Generally, studies reporting no significant differences between iso-caloric supplements have used shorter recovery/supplementation periods (3 h) and increased frequency of supplementation (5, 25). No significant difference was detected comparing CHO-PRO and HCHO despite an approximately 20% higher glycogen storage rate recorded for CHO-PRO (29). More frequent administration of supplements with high CHO content may potentially alter rates of CHO and PRO absorption, possibly limiting any advantage of PRO.

The mechanism by which CHO-PRO facilitates restoration of exercise capacity may differ according to mode of exercise performed prior to recovery (4). Data for exhaustive running and cycling protocols exist (3, 4, 9), however, data for resistance exercise is limited, and to our knowledge, this study represents the first evidence of enhanced restoration of exercise capacity using RT protocol. Previous research in this field failed to produce conclusive results (6), however, despite a lack of statistical significance mean TWC after ingestion of a CHO-PRO supplement was 16, 10 and 2% higher than after ingestion of LCHO, HCHO and CHO-fructose supplements, respectively. During this earlier study, it is possible that had glycogen stores been fully depleted, the difference in CHO uptake due to insulinotropic stimuli may have resulted in a significant glycogen restoration and subsequent performance outcome as postulated by other researchers (4, 8).

In conclusion, ingestion of a CHO-PRO supplement following exercise enhanced recovery and resulted in a greater work capacity compared with LCHO and HCHO supplements. This CHO-PRO induced enhancement of recovery was possibly due to higher rates of glycogen restoration after the initial glycogen depleting RT exercise protocol and better maintenance of blood glucose concentration during the TTF protocol. The AA present in the ingested CHO-PRO supplement may also have induced an ergogenic effect through an interaction with the CNS (18); possibly reducing feelings of lethargy associated with elevated serotonin concentrations. Previously, significantly greater glycogen restocking over a 240 min recovery period with CHO-PRO when compared with iso-caloric and iso-CHO supplements in fasted, glycogen-depleted participants has been reported (9). The current results are partly in agreement with data reported in trained endurance runners supplemented with higher rates of substrate at more frequent intervals throughout a 240 min recovery/supplementation period (4).

Further study is warranted in this area to determine the influence of peripheral and central factors of fatigue on the recorded enhanced performance outcomes as a result of an enhanced recovery with a CHO-PRO drink. Determination of glycogen utilised and glycogen restored would be particularly helpful in quantifying the true glycogen restoration effect of the drinks. These data, with additional analyses of blood borne markers such as insulin, urea, glycerol and FFA may allow a more complete picture of the peripheral and consequently, central factors limiting performance at high intensities and the fate of the constituents of the drinks at a cellular level. Such data would then allow athletes to conclude whether these so-called beverages truly warrant the name recovery drinks.

ACKNOWLEDGEMENTS

This study was funded by a grant from Britvic Ireland. The authors would like to thank the staff and players of the IRFU and Leinster Rugby.

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