The Effects of Postexercise Consumption of High-Molecular-Weight Versus Low-Molecular-Weight Carbohydrate Solutions on Subsequent High-Intensity Interval-Running Capacity

Chris McGlory and James P. Morton

The aim of this study was to determine the effects of postexercise ingestion of different-molecular-weight glucose polymer solutions on subsequent high-intensity interval-running capacity. In a repeated-measures design, 6 men ran for 60 min in the morning at 70% VO₂max. Immediately post- and at 1 and 2 hr postexercise, participants consumed a 15% low-molecular-weight (LMW) or high-molecular-weight (HMW) carbohydrate solution, at a rate of 1.2 g of carbohydrate/kg body mass, or an equivalent volume of flavored water (WAT). After recovery, participants performed repeated 1-min intervals at 90% VO₂max interspersed with 1 min active recovery (walking) until volitional exhaustion. Throughout the 3-hr recovery period, plasma glucose concentrations were higher (p = .002) during the HMW and LMW conditions than with WAT (M 7.0 ± 0.8, 7.5 ± 1.0, and 5.6 ± 0.2 mmol/L, respectively), although there was no difference (p = .723) between HMW and LMW conditions. Exercise capacity was 13 (43 ± 10 min; 95% CI for differences: 8–18; p = .001) and 11 min (41 ± 9 min; 95% CI for differences: 2–18; p = .016) longer with HMW and LMW solutions, respectively, than with WAT (30 ± 9 min). There was no substantial difference (2 min; 95% CI for differences: –5 to 10; p = .709) in exercise capacity between LMW and HMW solutions. Although this magnitude of difference is most likely trivial in nature, the uncertainty allows for a possible small substantial enhancement of physiological significance, and further research is required to clarify the true nature of the effect.

Keywords: intermittent exercise, muscle glycogen, resynthesis

Since the pioneering work of Bergstrom and colleagues in the 1960s (Bergstrom, Hermansen, Hultman, & Saltin, 1967; Bergstrom & Hultman, 1966, 1967), it has been well established that elevated preexercise levels of muscle glycogen can attenuate fatigue during prolonged exercise. A maximized preexercise muscle glycogen store is therefore considered essential for athletes who partake in prolonged bouts of physical activity. In addition to preexercise muscle glycogen stores, it is crucial that athletes undertake appropriate nutritional strategies in the postexercise period to maximize muscle glycogen resynthesis before their next training session. This is particularly important for athletes who train twice per day and have a recovery period of only 3–4 hr between training sessions, as is the case for athletes who compete in invasive team-sports games such as soccer and rugby.

Although some data have unequivocally demonstrated the importance of timing (Ivy, Katz, Cutler, Sherman, & Coyle, 1988) and quantity (Van Loon, Saris, Kruijshoop, & Wagenmakers, 2000) of carbohydrate consumed, other studies have shown that when glucose is intravenously administered, muscle glycogen resynthesis rates are significantly greater than with oral feeding (Hansen, Asp, Kiens, & Richter, 1999). These data suggest that the rate of gastric emptying and subsequent delivery to and transport across the intestinal mucosa may be a limiting factor to postexercise muscle glycogen resynthesis. Indeed, more recent research has shown that postexercise oral consumption of a unique high-molecular-weight (HMW) carbohydrate solution with low osmolality, that is known to enhance gastric emptying (Lieper, Piehl-Aulin, & Soderlund, 2000), augments glycogen resynthesis in the vastus lateralis muscle in a 2-hr postexercise period compared with a low-molecular-weight (LMW) solution with high osmolality (Piehl-Aulin, Soderlund, & Hultman, 2000). Furthermore, Stephens, Roig, Armstrong, and Greenhaff (2007) observed that postexercise ingestion of an HMW glucose polymer results in improved performance in exercise undertaken 2 hr later (total work output during a 15-min cycle time-trial test) compared with an LMW solution.

Although such data have proved insightful, there are a number of methodological factors that may have
contributed to such performance-enhancing effects. First, these authors administered the carbohydrate solution as a single bolus consisting of only 100 g of carbohydrate. Such a feeding strategy is not in accordance with guidelines recommending a carbohydrate ingestion rate of 1.2 g/kg body mass per hour to maximize postexercise muscle glycogen resynthesis (Broad & Cox, 2008). Second, although the exercise test was performed 2 hr after consumption of this single bolus, Pihl-Aulin et al. (2000) observed the enhanced glycogen resynthesis rates to be evident only in the initial 2 hr after glycogen-depleting exercise. Indeed, these authors observed glycogen resynthesis rates to be unaffected by the molecular weight of the carbohydrate consumed during the 2- to 4-hr postexercise period, despite a total carbohydrate intake of 300 g over the initial 90-min postexercise period. The performance-enhancement effects of the HMW carbohydrate observed by Stephens et al. (2007) may therefore only be apparent when total carbohydrate intake is below optimal levels and the duration of the recovery period is 2 hr or less. It is possible, therefore, that when carbohydrate is consumed at a rate known to maximize muscle glycogen resynthesis and the recovery period is greater than 2 hr, the performance-enhancing effects of HMW carbohydrates versus LMW carbohydrates are negated.

With this in mind, the aim of the current study was to investigate whether postexercise ingestion of an HMW glucose polymer, administered orally at the rate of 1.2 g/kg body mass for 3 hr, improves endurance capacity during a subsequent bout of high-intensity interval-running exercise compared with an LMW solution. We chose high-intensity interval running as our experimental protocol given the relevance of this type of activity to field sports that are characterized by intermittent activity.

**Materials and Methods**

**Participants**

Six healthy recreationally active men (age 20 ± 2 years, height 1.81 ± 0.05 m, body mass 78 ± 14 kg, VO$_2$max 50 ± 6 ml·kg$^{-1}·$min$^{-1}$) volunteered to participate in this study. All participants gave written and informed consent after details of the study procedures were fully explained. No participant had a history of smoking or heart disease, and none were under any pharmacological treatment during the course of the study. All participants refrained from exercise and alcohol intake for at least 48 hr before the testing sessions. The study was approved by the ethics committee of Liverpool John Moores University.

**Experimental Design**

Having initially been assessed for maximum oxygen uptake (VO$_2$max), all participants underwent three separate trials in a fully randomized (according to Altman, 1991) double-blind design that were separated by at least 7 days. In each trial, participants reported to the laboratory at 8:45 a.m. after an overnight fast and performed 60 min of running on a motorized treadmill at a velocity corresponding to 70% VO$_2$max. On completion, they rested in a semisupine position on a bed for 3 hr during which time they ingested either flavored water (WAT; Vovlic, Touch of Fruit—orange and peach, 1.2 kcal/100 ml, Danone Waters, UK) or one of two commercially available isocaloric 15% carbohydrate solutions containing an LMW (Lucozade Sport Body Fuel Powder, 47% dextrose, 43% maltodextrin, GlaxoSmithKline Consumer Healthcare, UK; 523 mOsmol/L) or HMW glucose polymer derived from 98–99% amylopectin waxy maize starch (Vitargo, Juicy Orange, Carbamyl, Karlskrona, Sweden; 82 mOsmol/L). The osmolality of both solutions was determined before the commencement of the study (The Advances Micro Osmometer, Model 3300, Massachusetts, USA). The solutions were administered orally to each participant immediately postexercise and at 1 and 2 hr postexercise at a carbohydrate ingestion rate of 1.2 g/kg body mass, according to guidelines considered optimal to maximize muscle glycogen resynthesis (Broad & Cox, 2008). The solutions were administered by independent researchers with no knowledge of the study aims and design (the laboratory technicians of our laboratory, cited in the Acknowledgments section) in opaque containers to prevent the recognition of each solution between trials through color. A list of ingredients and nutritional information of all beverages (as provided by the manufacturers) are shown in Table 1. Although the participants were aware of the aims of the study, they were not informed of the brands of carbohydrate beverage being investigated. Each participant consumed an identical volume of solution at each ingestion time point between trials (ranging from 504 to 712 ml between participants). At 10 min postadministration of each solution, ratings of gastrointestinal discomfort were obtained on a scale of 1 to 10 (1=no discomfort, 10=severe discomfort). After the 3-hr recovery period (at approximately 1 p.m.), the participants were then required to run repeated 1-min intervals on a motorized treadmill at a velocity corresponding to 90% VO$_2$max, interspersed with 1 min active recovery (corresponding to a walking pace of 5 km/hr) until volitional exhaustion, as a measure of subsequent exercise capacity. Fingertip capillary blood samples were obtained immediately before and after both exercise protocols and at 30-min intervals throughout the recovery period. All experimental protocols were completed at the same time of day to minimize the effects of circadian variation on the physiological responses to exercise and exercise capacity (Reilly, 1990).

**Assessment of VO$_2$max**

All participants were initially assessed for VO$_2$max using an incremental exercise test performed on a motorized treadmill. The test began with a 2-min stage at a treadmill speed of 10 km/hr followed by 2-min stages at 12, 14, and 16 km/hr. After completion of the 16-km/hr stage, the treadmill inclined by 2% every 2 min thereafter until volitional exhaustion. Expired gas was collected.
Exercise Protocol 1: Glycogen-Depleting Exercise

When participants entered the laboratory at 8:45 a.m., nude body mass was measured (Seca, Gmbh & Co., Germany) and a preexercise fingertip capillary blood sample was collected. Participants then ran on a motorized treadmill (HP Cosmos, Germany) at a velocity corresponding to 70% VO$_{2\text{max}}$ for 60 min. This intensity and duration of exercise have been previously shown to deplete muscle glycogen concentration by approximately 45% in the vastus lateralis muscle of recreationally active males (Tsintzas, Williams, Boobis, & Greenhaff, 1995). It is likely that the absolute glycogen utilization rates reported by those authors would be similar to that occurring in the current study considering the similarity in training status of the participants used in both investigations. We deliberately chose an exercise protocol that depletes muscle glycogen by this magnitude as opposed to a true glycogen-depleting protocol (Stephens et al., 2007) because we consider this more representative of the average training intensity imposed on athletes involved in invasive team sports. Participants were permitted to ingest water ad libitum throughout the protocol, with the pattern of consumption repeated for the subsequent trials. On completion of this initial morning exercise trial, a postexercise fingertip capillary blood sample was collected and nude body mass was measured after drying.
Heart rate (Polar S 610i, Kempele, Finland) and ratings of perceived exertion (RPE; Borg, 1970) were measured at 10-min intervals throughout exercise.

Exercise Protocol 2: Exercise-Capacity Test

After the 3-hr recovery period (at approximately 1 p.m.) nude body mass was measured and a preexercise capillary blood sample was obtained. Participants then performed repeated 1-min intervals on a motorized treadmill (HP Cosmos, Germany) at a velocity corresponding to 90% $\text{VO}_{2\text{max}}$ interspersed with 1-min active recovery periods (at a walking pace of 5 km/hr) until volitional exhaustion as a measure of endurance capacity. (The intermittent nature of this protocol was chosen to replicate the activity patterns and the metabolic stress of speed endurance training sessions and is therefore of relevance to athletes who compete in invasive field-based sports such as soccer and rugby.) Participants were unaware of the time or distance they had covered until the end of the study. On exhaustion, a postexercise fingertip capillary blood sample was collected. Heart rate (Polar S 610i, Kempele, Finland) and RPE (Borg, 1970) were measured at 10-min intervals throughout exercise. An average heart rate and RPE value (as calculated from the average of the values obtained at 10-min intervals and at the point of exhaustion) were used to compare participants’ physiological responses during exhaustive exercise between trials. To ensure participant compliance with performing repeated intervals at this exercise intensity, all participants were familiarized with the running speeds of this protocol by completing approximately 15 min of exercise (i.e., seven intervals) at least 3 days after the initial $\text{VO}_{2\text{max}}$ test and at least 3 days before commencement of the main experimental trials.

Dietary Controls

For 2 days before the initial trial, participants completed a 2-day food diary and activity log. Subsequent dietary analysis was performed with the software program Microdiet (Downlee Systems, Ltd., UK). Nutritional analysis revealed that participants’ daily energy intake was $1,877 \pm 633 \text{kcal (46% \pm 10% carbohydrate, 15% \pm 8% protein, 39% \pm 16% fat)}$. In an effort to ensure similar preexercise muscle glycogen stores before subsequent trials, all participants repeated this dietary and activity pattern in the 2 days preceding their remaining trials.

Blood Sampling

Capillary blood was taken from each participant’s fingertip using a 1.8-mm safety lancet (Sarstedt, Aktiengesellschaft & Co., Sweden) after sterilization with a preinjection medical swab (Medlock Medical Ltd., Oldham). Samples were collected in 3-ml microvettes (Sarstedt, Germany) and were left on ice (for no more than 30 min) until being subsequently centrifuged (Hettich Zentrifugen, Germany) for 10 min at 3,000 rpm. After centrifugation, plasma was removed and stored at $-80 \degree \text{C}$ for later analysis. Plasma lactate and glucose concentrations were determined according to commercially available kits (Daytona RX, Randox Laboratories Ltd., Crumlin, UK). All postexercise samples were corrected for changes in plasma volume according to Dill and Costill (1974) based on the hemoglobin (Hemocube AB, Angelholm, Sweden) and hematocrit (Hawksley microhematocrit reader, Gelman Hawksley Ltd., England) values that were measured within 1 min of collecting each sample.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (version 15 for Windows, SPSS Inc., Chicago, IL). Before analysis, all data were analyzed for normal distribution using the Shapiro-Wilk test. Differences in any exercise-related variables between trials (i.e., heart rate, RPE, plasma lactate, plasma glucose) and gastrointestinal discomfort during recovery were analyzed using a two-way repeated-measures general linear model in which the within factors were time (i.e., exercise response) and condition (i.e., WAT vs. HMW vs. LMW). Differences in exercise capacity between conditions were assessed using a one-way repeated-measures general linear model. When there was a significant difference, a paired $t$ test using Bonferroni’s corrections for multiple comparisons was employed for post hoc analysis. All data are presented as $M \pm SD$, and $p$ values <.05 indicate statistical significance.

In keeping with recent trends in methods of inferential statistics and guidelines for reporting statistics in physiology-related journals (Batterham & Hopkins, 2006; Curran-Everett & Benos, 2004; Hopkins, Marshall, Batterham, & Hanin, 2009), we also report uncertainty of outcomes as 95% confidence intervals (95% CI) and make probabilistic magnitude-based inferences about the true (large-sample) values of outcomes by qualifying the likelihood that the true effect represents a substantial change (i.e., the smallest worthwhile effect), as described by Batterham and Hopkins. For our primary outcome variable of exercise capacity, we deemed a difference in exercise capacity of 5 min between HMW and LMW solutions a substantial change of physiological relevance for performance. This 5-min threshold value is based on previous (though limited) available data. For example, Piehl-Aulin et al. (2000) observed an absolute increase in muscle glycogen content of 35 mmol/kg dry weight after ingestion of HMW versus LMW solutions in favor of the former. Furthermore, Krustrup et al. (2006) observed muscle glycogen utilization during 4.3 min of high-intensity interval running to be 33 mmol/kg dry weight (i.e., 7.7 mmol/kg per minute of exercise). Based on such exercise-induced glycogen utilization rates and the increased glycogen resynthesis reported by Piehl-Aulin et al., we estimated an enhanced exercise capacity greater than 4.54 min (as calculated by dividing 35 mmol/kg by the proposed exercise utilization rate of 7 mmol/kg per...
minute) with ingestion of the HMW solution and therefore defined a difference in exercise capacity of 5 min between HMW and LMW solutions as a substantial change. To provide probability-based practical inference, an effect was considered mechanistically unclear if its CI included both substantial positive and negative values.

Results

Physiological and Metabolic Responses to the Glycogen-Depleting Exercise Protocol

Mean heart rates during the protocol were 178 ± 12, 181 ± 14, and 178 ± 14 beats/min for the HMW, LMW, and WAT solutions, respectively (95% CI for mean differences between HMW–LMW, HMW–WAT, and LMW–WAT were −5 to 2, −3 to 2, and −2 to 4). Mean RPE during exercise was 16 ± 2 for each condition (95% CI for mean differences between HMW–LMW, HMW–WAT, and LMW–WAT were −1 to 2, −1 to 0.5, and −2 to 1). Mean postexercise plasma lactate concentrations were 4.9 ± 1.4, 4.4 ± 1.1, and 5.2 ± 2.7 mmol/L for the HMW, LMW, and WAT solutions, respectively (95% CI for mean differences between HMW–LMW, HMW–WAT, and LMW–WAT were −0.7 to 1.4, −2 to 1.6, and −2 to 1.2). There was no significant difference (p = .352, .247, and .607) in any of the aforementioned variables between trials, thus demonstrating that the physiological stress imposed by this initial exercise stress was similar between conditions.

Plasma Glucose Response and Rates of Gastrointestinal Discomfort to Administration of Carbohydrate Solutions During the 3-hr Recovery Period

Plasma glucose concentrations were significantly higher (p = .002) throughout the recovery period during the HMW and LMW conditions than the WAT condition (see Figure 1). However, there was no significant difference (p = .723) in plasma glucose concentration between the HMW and LMW carbohydrate solutions throughout the recovery period. Mean plasma glucose concentrations were 7.0 ± 0.8, 7.5 ± 1.0, and 5.6 ± 0.2 mmol/L for the HMW, LMW, and WAT solutions, respectively (95% CI for mean differences between HMW–LMW, HMW–WAT, and LMW–WAT were −1.9 to 0.9, 0.3–2.3, and 0.3–3.5). Rates of gastrointestinal discomfort at 10 min after each of the three feedings were significantly higher throughout the recovery period during the HMW condition (7 ± 1, 7 ± 1, 7 ± 2) than both the LMW condition (3 ± 2, 3 ± 1, 4 ± 1; p = .011) and WAT condition (2 ± 1, 3 ± 1, 3 ± 2; p = .003). However, there was no significant difference in rates of gastrointestinal discomfort between the LMW and WAT conditions (p = .652). The 95%

Figure 1 — Plasma glucose response after ingestion of high-molecular-weight (HMW) and low-molecular-weight (LMW) carbohydrate solutions and water (WAT) during the 3-hr recovery period. *Significant difference from the WAT condition, p < .05.
CI for mean differences in gastrointestinal discomfort between HMW–LMW, HMW–WAT, and LMW–WAT were 0.97–6.3, 2–7.6, and –1.7 to 4.2, respectively.

**Total Exercise Time to Exhaustion and Physiological and Metabolic Responses to the Exercise-Capacity Protocol**

In relation to our primary outcome variable, total exercise time (i.e., high-intensity intervals plus active recovery) to exhaustion for WAT, LMW, and HMW was 30 ± 9, 41 ± 9, and 43 ± 10 min, respectively (see Figure 2). There was no significant difference in run time to exhaustion between LMW and HMW solutions (p = .709), although the exercise capacity in the carbohydrate trials was significantly longer than in the WAT trial (p = .001). The 95% CI for mean differences in exercise capacity between HMW–LMW, HMW–WAT, and LMW–WAT were –5 to 10, 8–18, and 2–18, respectively. Although participants’ average heart rate during exercise showed no significant differences (p = .72) between conditions (169 ± 5, 169 ± 4, and 168 ± 5 beats/min for the HMW, LMW, and WAT solutions, respectively; 95% CI for mean differences between HMW–LMW, HMW–WAT, and LMW–WAT were –5 to 6, –2 to 4, and –4 to 5), corresponding RPE values were significantly higher in the WAT trial (17 ± 0.4) than in the HMW (15 ± 0.3; p = .003) and LMW conditions (15 ± 0.4; p = .027). There was, however, no significant difference (p = 1.00) in RPE between the two carbohydrate conditions. The 95% CI for mean differences in RPE between HMW–LMW, HMW–WAT, and LMW–WAT were –1 to 1, –2 to –1, and –2 to –0.1, respectively. Plasma lactate significantly increased with exercise (p = .001), although there was no significant difference (p = .385) between conditions. Plasma lactate values at exhaustion were 7.2 ± 1.3, 8.2 ± 1.1, and 6.6 ± 3.5 mmol/L for the HMW, LMW, and WAT conditions, respectively (see Figure 3). The 95% CI for mean differences in lactate between HMW–LMW, HMW–WAT, and LMW–WAT were –1.3 to 1.2, –2.4 to 4.1, and –1.9 to 3.7.

**Discussion**

The aim of the current study was to investigate whether postexercise ingestion of an HMW glucose polymer, administered orally at the rate of 1.2 g/kg body mass per hour for 3 hr, improves endurance capacity during a subsequent bout of high-intensity interval running exercise compared with an LMW solution. As expected, both HMW and LMW solutions significantly and substantially improved exercise capacity compared with ingesting WAT only, and participants’ RPEs were also higher in the WAT condition. However, we observed no significant or substantial difference in exercise capacity between LMW and HMW solutions. Nevertheless,
the uncertainty of outcomes reported from inferential statistics allows for a possible small substantial enhancement of physiological significance. The latter approach in making meaningful inferences about magnitudes is particularly important given the small sample size employed here and also considering that the 95% CI for HMW–LMW differences (i.e., −5 to 10 min) includes values that are both substantially positive and negative.

Ingestion of a 15% HMW carbohydrate solution immediately after glycogen-depleting exercise augments glycogen resynthesis at 2 hr postexercise compared with an LMW solution (Piehl-Aulin et al., 2000), possibly attributable to enhanced gastric emptying over the initial 10 min after ingestion (Leiper et al., 2000). Although both studies confirmed enhanced glycogen resynthesis and gastric emptying, respectively, there were no differences in either study in blood glucose or serum insulin concentration between the HMW and LMW solutions during the postprandial period. In contrast, Stephens et al. (2007) observed higher blood glucose concentrations after ingestion of an HMW solution at 10, 20, 30, and 40 min postingestion compared with the LMW carbohydrate solution. The discrepancy in such data sets and those presented here may be a result of differences in feeding strategy. Indeed, Stephens et al. administered their solution as a single bolus consisting of 10% carbohydrate, whereas we and others (Piehl-Aulin et al., 2000) administered the carbohydrate solution as a 15% beverage given as repeated feedings. It is possible, therefore, that the enhanced glucose response observed by Stephens et al. was caused by enhanced gastric emptying of the single 10% solution (consisting of 100 g only) compared with the repeated ingestion of 15% solution (consisting of total carbohydrate delivery of approximately 300 g), given that concentration of carbohydrate is known to influence gastric emptying (Vist & Maughan, 1995). Furthermore, the use of repeated feedings as opposed to a single bolus may have resulted in a more sustained insulin response, a factor that could affect both plasma glucose appearance and disposal. We also acknowledge that it is difficult to compare between studies because of differences in structure of carbohydrate administered; the HMW solution given by Leiper et al. (2000) and Piehl-Aulin et al. was composed of 78% amylopectin and 22% amylase, whereas the one we and Stephens et al. administered was derived from 98% waxy maize corn starch.

Stephens et al. (2007) found that postexercise ingestion of the HMW solution improved exercise performance (total work output) by 10% during an all-out 15-min cycling time trial compared with the LMW solution. In contrast, we report here no substantial difference (2 min, 95% CI for differences −5 to 10; \( p = .709 \)) in exercise capacity between LMW and HMW solutions. Although this magnitude of difference may be trivial in nature, the uncertainty allows for a possible small substantial enhancement of physiological significance. A number of methodological differences between studies, such as feeding strategy, the extent of the glycogen-depleting-exercise protocol, exercise modality, and choice of performance test (although we suggest that an exercise capacity test

![Figure 3](image-url) — Plasma lactate concentrations before and after the exercise-capacity test in the high-molecular-weight (HMW) and low-molecular-weight (LMW) carbohydrate solutions and water (WAT) conditions. *Significant difference from preexercise values, \( p < .05 \).
better reflects preexercise muscle glycogen concentration than an all-out 15-min performance time trial), may have contributed to the discrepancy between data. Indeed, Stephens et al. employed a true glycogen-depleting protocol known to almost fully deplete muscle glycogen stores and that poses considerable liver glycogen depletion (Casey et al., 2000). Casey et al. observed that when carbohydrate intake after glycogen-depleting exercise is suboptimal (<1 g/kg body mass), there is a modest correlation between change in liver glycogen content and subsequent exercise capacity, suggesting that under such physiological conditions increased glucose oxidation from enhanced liver glycogen availability is a contributing factor to performance. Stephens et al. therefore suggested enhanced liver glycogen resynthesis as a potential mechanism to explain the observed performance increase after ingestion of HMW solutions compared with LMW solutions. It is possible, however, that when carbohydrate is ingested at a rate known to maximize muscle glycogen resynthesis (as in the current study), there is no augmented glycogen resynthesis in either muscle or liver after ingestion of HMW solutions compared with LMW solutions because the maximal capacity for intestinal absorption of glucose has already been reached. In this way, the contracting musculature will have the same energy availability during a subsequent exercise challenge. Further studies using magnetic-resonance spectroscopy are needed to clarify this issue. Moreover, future research using larger samples and other previously validated models of high-intensity interval exercise such as the Yo-Yo IR2 (Krstrup et al., 2006) and the LIST (Nicholas, Nuttal, & Williams, 2000) are also warranted to clarify the true nature of the effect of HMW versus LMW solutions on exercise capacity during high-intensity interval exercise.

From a practical perspective it is also important to note that participants reported poor palatability with the HMW solution, and rates of gastrointestinal discomfort were higher with the HMW solution than with the LMW and WAT solutions. This is likely caused by the high absolute amount of carbohydrate consumed to meet the required ingestion rate of 1.2 g/kg body mass. Similar to Lieper et al. (2000), we observed that the HMW solution when prepared in this quantity has a tendency to form pastelike properties. To counteract this effect, more frequent but smaller feedings may therefore be necessary.

In summary, our data demonstrate that postexercise ingestion of an HMW glucose polymer, administered orally at the rate of 1.2 g/kg body mass per hour for 3 hr, does not induce substantial improvements in exercise capacity during a subsequent bout of high-intensity interval running compared with a commercially available LMW solution. However, the uncertainty of outcomes reported from inferential statistics allows for a possible small substantial enhancement of physiological significance. Further studies using larger sample sizes and a variety of feeding strategies and exercise protocols are required to clarify the true nature of the effect. To provide a mechanistic insight to the potential performance-enhancing effects of HMW carbohydrates, such research should also be supported by measurements of gastric emptying and muscle and liver glycogen resynthesis.

Acknowledgments

The authors thank Prof. Greg Atkinson and Dr. Mark Scott for assistance with statistical analysis of the data. We also extend our appreciation to Andrew Hulton, Robert Kennett, and Lynn Hubby for their excellent technical assistance during data collection.

References


