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„Athlete Training Management“

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Nutrition and Supplements for Endurance and Ultra-Endurance Athlete

Dr Dalia Malkova

School of Medicine, Dentistry and Nursing

College of Medical, Veterinary & Life Sciences

University of Glasgow, Scotland, UK

Email: Dalia.Malkova@glasgow.ac.uk

Nutrition and Supplements for Endurance and Ultra-Endurance Athlete

Synopses

This talk will summarize the latest evidence-based nutrition and supplement recommendations for endurance and ultra-endurance athletes and consider some controversial subjects in order to equip the coaches and athletes to assist training sessions and competition events and optimize health and performance of the athlets.

Importance of the Understanding of Nutritional Requirements in Endurance and Ultra-Endurance athletes

- Participation in Endurance Events has increased with 3.5 million triathlon participants worldwide.
- In recent years, there has been shift from standard marathon races to other such as mud runs, color runs, and obstacle course races.
- Ultra-endurance events, typically defined as events lasting at least 4 to 6 hours duration, are gaining popularity.
- Endurance events exert on the body in terms of fatigue, sub-optimal nutrition, and energy deficit.

Nutrients **2019**, *11*, 1289

Exercise Performance and Carbohydrate Intake

- The realization that the performance of muscular exercise is influenced by the preceding diet is not new. Christensen and Hansen (1939) showed that endurance capacity in prolonged work was enhanced if a diet high in carbohydrate was consumed in the days prior to exercise, and was reduced by consumption of a low- carbohydrate diet.

- Inadequate glycogen availability results in reduced endurance exercise capacity and an inability to continue exercise because of impaired excitation–contraction coupling once glycogen stores are depleted (Schweitzer et al, 2017)

- Athletes training an competing in endurance events lasting up to 3 hours are CHO dependent.

- Thus, to meet daily demands of training sessions competitive athletes select CHO rich diet.

Key Recommendation for Macronutrient Intake (Exercise Duration in Italics within parentheses)

Nutrient	Daily Requirements	Pre-Exercise	During Exercise	Post-Exercise
Carbohydrate	5–7 g/kg/day *(1 h/day)* 6–10 g/kg/day *(1–3 h/day)* 8–12 g/kg/day *(4≥ h/day)*	6 g/kg/day *(<90 min)* 10–12 g/kg/day *(> 90 min)* + 1–4 g/kg (1–4 h prior to event)	30–60 g/h *(<2.5 h)* 60–70 g/h *(>2.5 h)* 90 g/h *(>2.5 h, if tolerable)*	8–10 g/kg/day (first 24 h) 1.0–1.2 g/kg/h (first 3–5 h) or 0.8 g/kg/h + protein (0.3 mg/kg/h) or caffeine (3 mg/kg)
Protein	1.4 g/kg/day 0.3 g/kg every 3–5 h	0.3 g/kg immediately prior (or post–exercise)	0.25 g/kg/h (if high intensity/eccentric exercise)	0.3 g/kg within 0–2 h (or pre-exercise)
Fat	Do not restrict to <20% total caloric energy Unclear role of CLA, omega-3, MCT supplements Consider limiting fat intake only during carbohydrate loading, or pre-race if GI comfort concerns			

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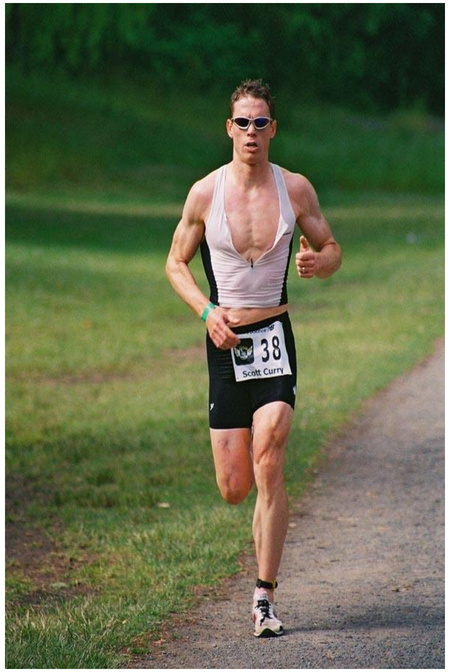
Role of High Carbohydrate (CHO) Intake for Endurance Performance

- Seven trained runners performed two 11-day trials of intensified training (IT) conducted in a randomised cross-over design separated by a 10-day washout period.
- During one trial subjects received a diet containing ~**8.5 g** of CHO kg/day (HCHO trial) and during another trial a diet containing ~ **5.5 g** CHO kg/ day (CON trial).
- On days 6, 7, 9 and 10 of both trials subjects were asked to run a 16 km course as fast as possible.



Achten et al, J Appl Physiol, 2004, 96, 1331-1340

Role of High Carbohydrate (CHO) Intake for Endurance Performance

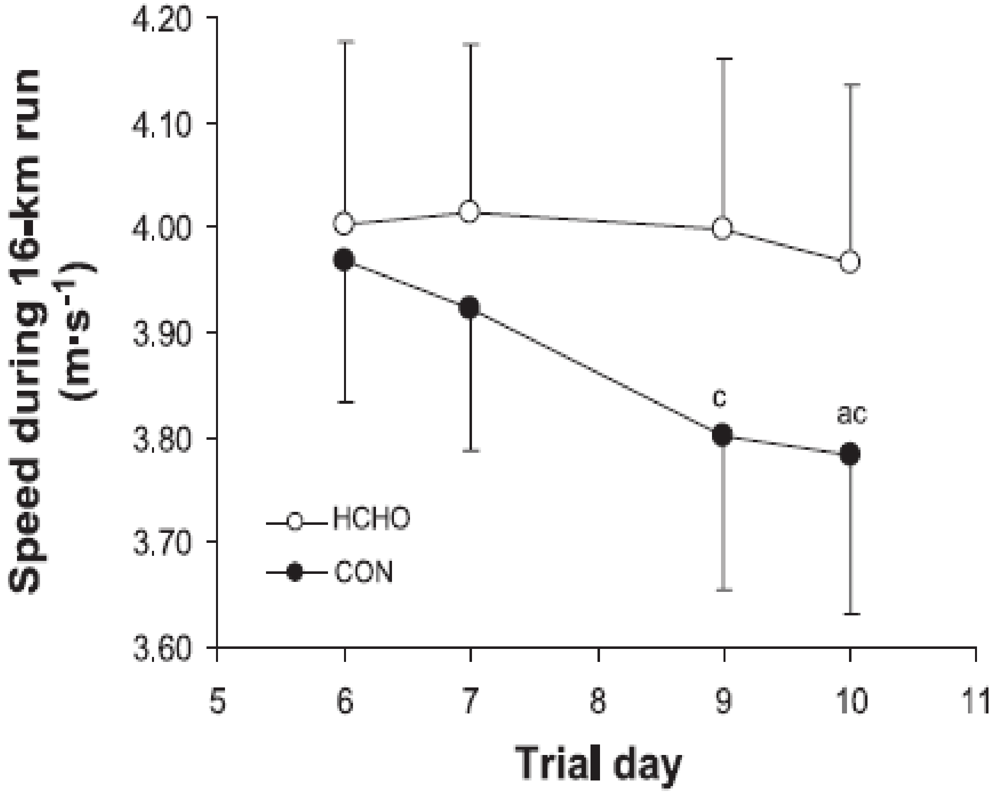
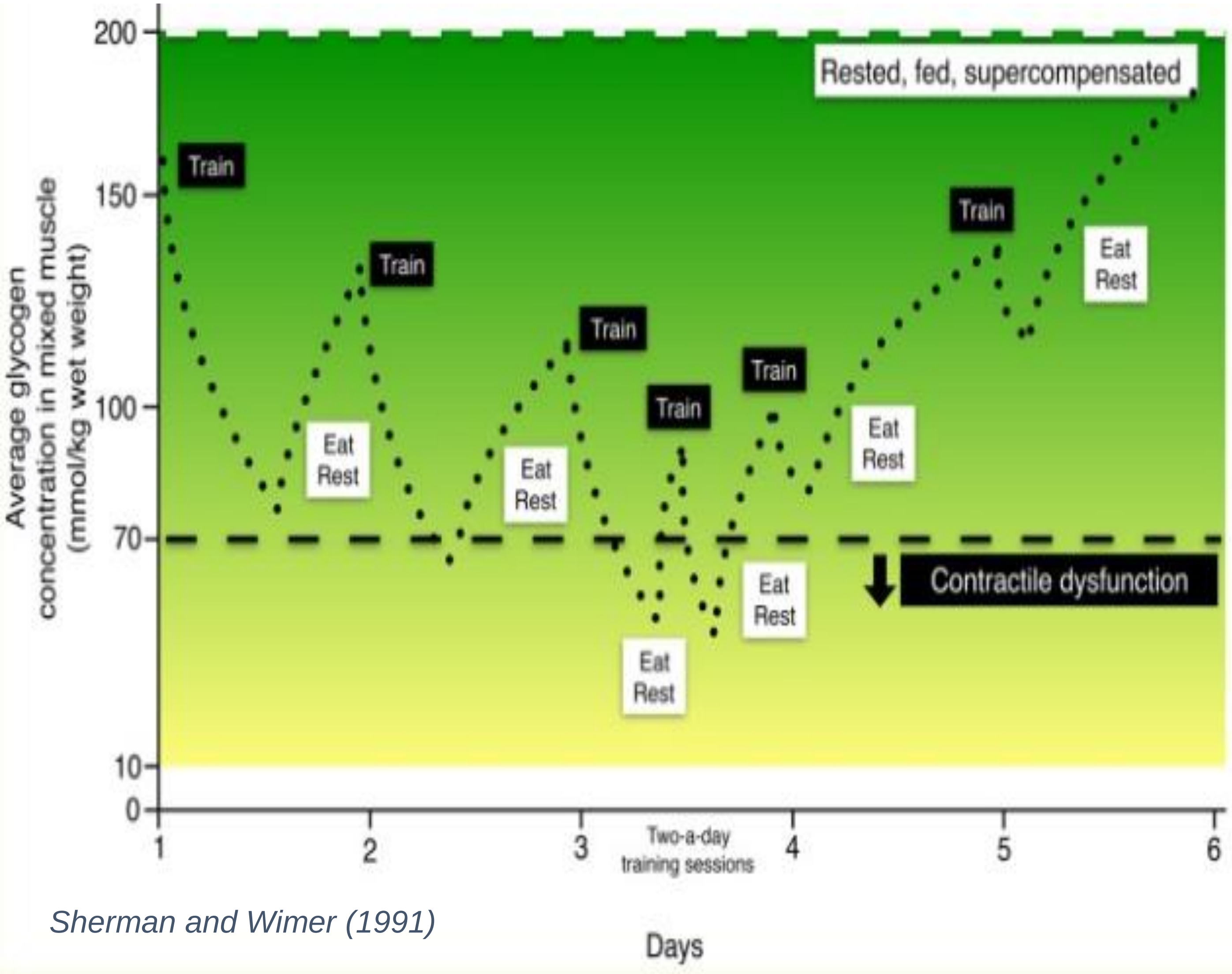


Fig. Running speeds during 16-km run on days 6, 7, 9 and 10. Values and Mean ± SE.

a - different from day 6; **c** - different from corresponding day in HCHO trial.

Achten et al, J Appl Physiol, 2004, 96, 1331-1340

Muscle glycogen levels during training



Sherman and Wimer (1991)

Muscle glycogen levels can vary widely during training, only reaching supercompensated levels after a few days of rest and light training.

Levels decline during training sessions and are partially restored during subsequent rest and after adequate carbohydrate intake.

During hard two-a-day training sessions (day 3), glycogen concentration can be lowered to the point at which contractile dysfunction (fatigue) occurs.

Athletes typically train with muscle glycogen stores that are adequate to meet the demands of training (between 75 and 150 mmol/kg wet weight) even though those stores might be considered suboptimal.

Carbohydrate Intake and Muscle Glycogen in Competitive Runners during Days of Intense Training

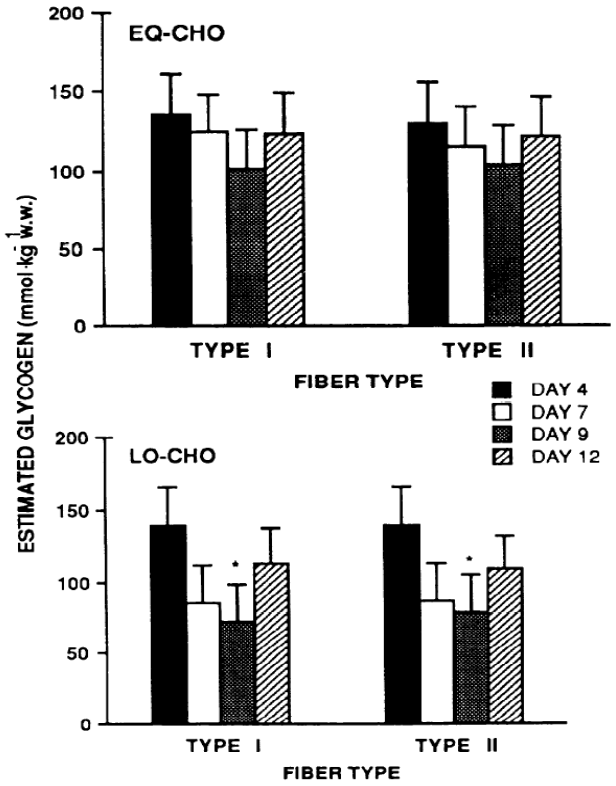


FIG. 3. Estimated glycogen content of type I and II muscle fibers during EQ-CHO and LO-CHO regimens. Glycogen content was estimated from mean weighted optical density values determined by photometric densitometry. * Significantly different from control, $P < 0.05$. See legend of Fig. 1 for definition of abbreviations.

On two separate occasions, 10 highly trained distance runners increased their training load for 5 days (20 km/day, approximately 80% maximal O2 consumption) while eating a diet whose carbohydrate composition either equaled (EQ-CHO) or contained approximately 50% of the runner's estimated daily expenditure (LO-CHO).

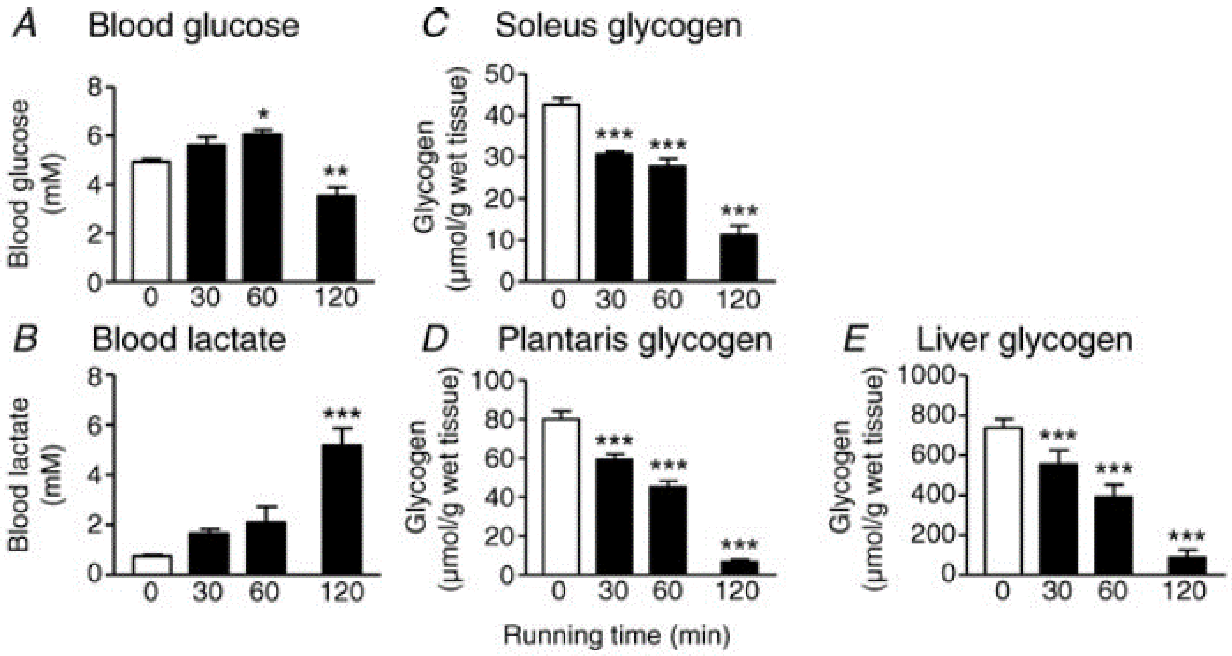
When CHO intake was only approximately 50% (LO-CHO) of the energy requirements there was a marked depletion of muscle glycogen stores, particularly in type I fibers, and a concomitant decrease in running economy and increased perception of fatigue

Kirwan et al. J Appl Physiol 1988 65(6):2601-6.

Brain glycogen decreases during prolonged exercise

T. Matsui, S. Soya, M. Okamoto, Y. Ichitani, K. Kawanaka, H. Soya

J Physiol 589.13 (2011) pp 3383–3393 3383



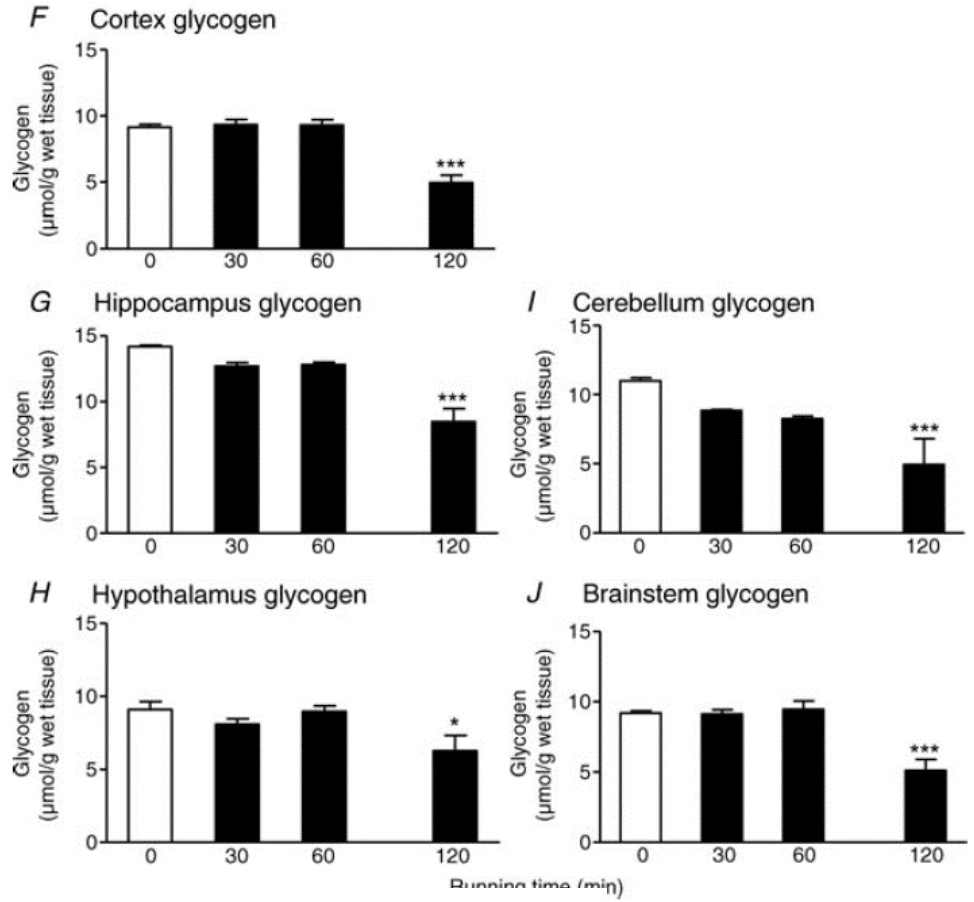


Figure 2. Blood glucose and glycogen levels in muscles, the liver and several brain loci, immediately after treadmill running exercise for 0 (pre-exercise), 30, 60 and 120 min
A, blood glucose levels; *B*, blood lactate levels; *C*, soleus glycogen levels; *D*, plantaris glycogen levels; *E*, liver glycogen levels; *F*, cortex glycogen levels; *G*, hippocampus glycogen levels; *H*, hypothalamus glycogen levels; *I*, cerebellum glycogen levels; and *J*, brainstem glycogen levels. Data represent the mean ± SEM ($n = 5$–6 rats). $*P < 0.05$; $**P < 0.01$; $***P < 0.0001$ compared to pre-exercise (Dunnett's *post hoc* test).

Glycogen depletion must not be the only determiner of fatigue

- In the even after 4.5 h of cycling at 70% of maximum O_2 consumption (VO_{2max}) when CHO stores should be entirely depleted, elite athletes can still run at 16 km/h for an additional 2.5 h at 66% VO_{2max} .

- Consequently, other CHO sources such as lactate utilization and other mechanisms such as increased capability to oxidize fat are postulated to account for this effect and clinicians should consider this when counseling athletes.

Burke et al., *J. Sports Sci.* **2011**, *29* (Suppl. 1), S17–S27.

Rethinking Fat as a Fuel for Endurance Exercise

Some ultra-endurance athletes have recently become interested in keto-adaptation (becoming "fat-adapted," or "training low") with a high fat, low carbohydrate diet

This renewed interest is based on the higher fat oxidation in lower intensity (<70% VO_{2max}) exercise states typically seen in ultra-endurance events

In the "train low" state of low carbohydrate availability, upregulation of fat oxidation pathways does occur, albeit at the expense of carbohydrate metabolism downregulation

Rethinking Fat as a Fuel for Endurance Exercise

- If performance is not an issue, becoming fat-adapted and exercising at low (<70% VO_{2max}) intensities therefore may improve lipolysis and promote weight loss in the overweight athlete.

- However, if the athlete's focus is on racing and improving performance times, a high fat, low carbohydrate diet restricts that athlete's ability to train and race at high intensities.

Getzin et al. Curr. Sports Med. Rep. 2017;16:240–246.

“Train low, race high”

- Periodically training in low glycogen/ low glucose availability states may stimulate upregulation of fat oxidation, spare muscle glycogen, and prolong time to exhaustion and be advantage in ultra-endurance events when intensity is typically under 70% of VO2 max.
- Some athletes decided to load with CHO just prior to the event and so they “train low, race high”. This would maximise both fat oxidation pathways at lower intensities (<70% VO2 max) and glucose and glycogen oxidation pathways at higher intensities (>70%VO2max)
- However, prolonged time spend in “ train low” may reduce athletes tolerability to maintain training load and thus quality of all training.

Enhanced Endurance Performance by Periodization of Carbohydrate Intake: "Sleep Low" Strategy

- Twenty-one triathletes were divided into two groups: a "sleep-low" (SL) (n = 11) and a control (CON) group (n = 10)

- Sleep low (SL) group conducted a 3-wk training-diet intervention comprising three blocks of diet-exercise manipulations:

  1) "train-high" interval training sessions in the evening with high-CHO availability,

  2) overnight CHO restriction ("sleeping-low")

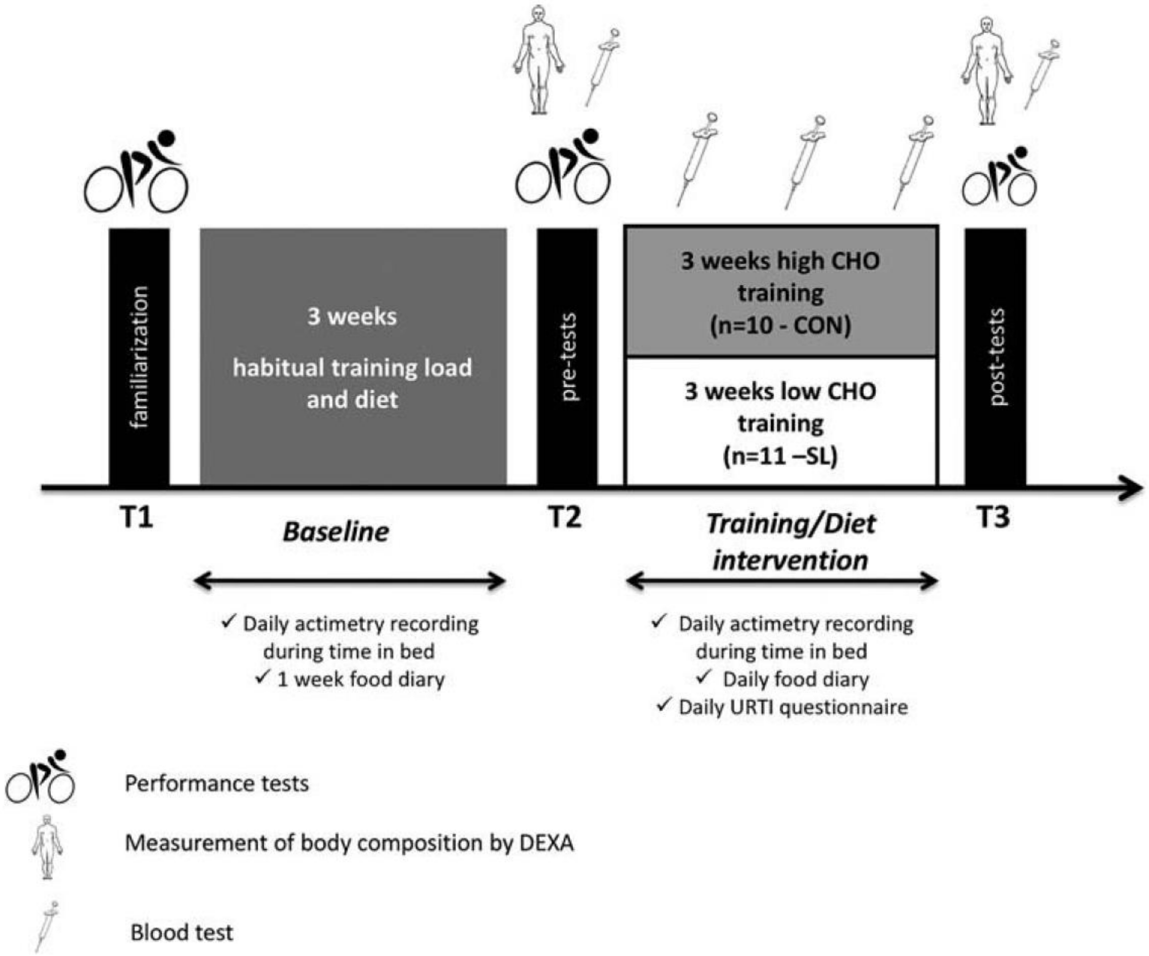
  3) "train-low" sessions in the morning with low endogenous and exogenous CHO availability.

- CON group followed the same training program but with high CHO availability throughout training sessions (no CHO restriction overnight, training sessions with exogenous CHO provision).

- Daily Intake of CHO in both groups was 6g/kg/day

Marquet et al, Med Sci Sports Exerc, 2016 ;48(4):663-72

Enhanced Endurance Performance by Periodization of Carbohydrate Intake: "Sleep Low" Strategy



Marquet et al, Med Sci Sports Exerc, 2016 ;48(4):663-72

Enhanced Endurance Performance by Periodization of Carbohydrate Intake: "Sleep Low" Strategy

10-km running performance:
Control: -0.10% ± 2.03%;
"Sleep Low“: -2.9% ± 2.15%;

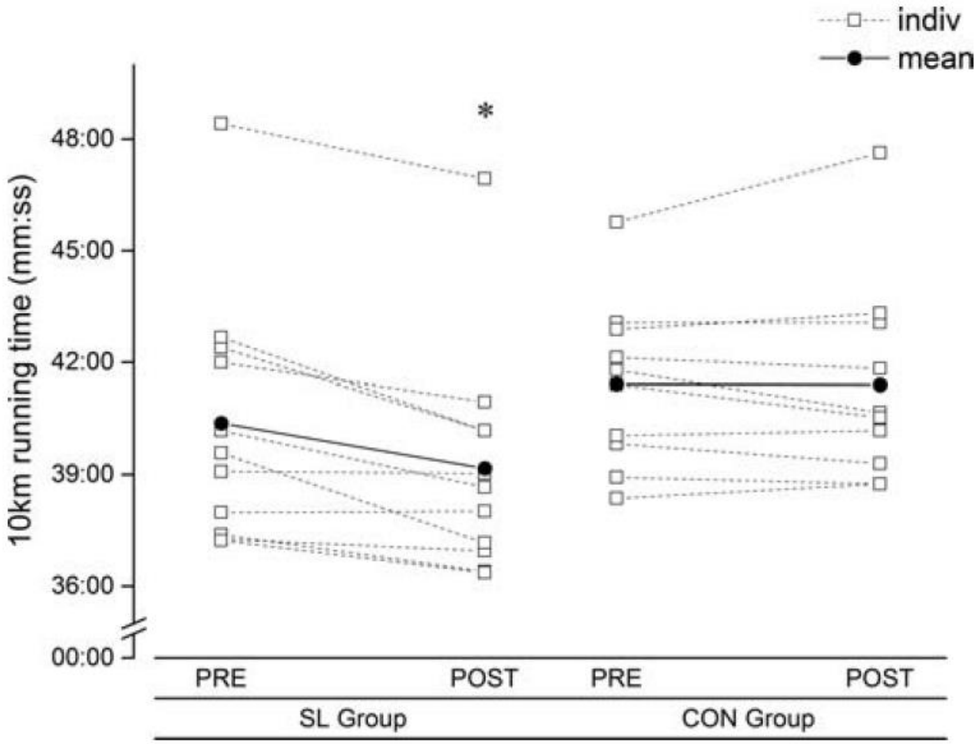


FIGURE 2—Ten-kilometer running performance PRE and POST 3 wk of training with periodized CHO availability (SL group) versus training with maintained CHO availability (CON group). Individual changes (*dashed lines*) and group mean (*continuous lines*). *$P < 0.05$ compared with PRE SL values.

Marquet et al, Med Sci Sports Exerc, 2016 ;48(4):663-72

Enhanced Endurance Performance by Periodization of Carbohydrate Intake: "Sleep Low" Strategy

- There was a significant improvement in delta efficiency during submaximal cycling for SL versus CON

  Control: +1.4% ± 9.3%;

  "Sleep Low": +11% ± 15% P < 0.05).

- SL improved supramaximal cycling to exhaustion at 150% of peak aerobic power:

  Control: +1.63% ± 12.4%

  "Sleep Low": +12.5% ± 19.0% (P = 0.06)

- Fat mass was decreased in SL

  Control: 2.6 ± 7.4;

  "Sleep Low": -8.5% ± 7.4% (P < 0.01)

Marquet et al, Med Sci Sports Exerc, 2016 ;48(4):663-72

Enhanced Endurance Performance by Periodization of Carbohydrate Intake in trained endurance athletes: "Sleep Low" Strategy

Conclusion

Short-term periodization of dietary CHO availability around selected training sessions promoted significant improvements in submaximal cycling economy, as well as supramaximal cycling capacity and 10-km running time in trained endurance athletes

Marquet et al, Med Sci Sports Exerc, 2016 ;48(4):663-72

Metabolic characteristics of keto-adapted ultra-endurance runners

- Participants: male ultra-endurance runners 21-45 years of age habitually consuming either a traditional high-carbohydrate diet (HC, n=10) and a low-carbohydrate diet (LC, n=10).
- The athletes were in the top 10% of finalists competing in sanctioned running events > 50 km and/or triathlons of at least half ironman distance (113 km).
- The athletes consuming an LC diet, defined as a 20% energy from carbohydrate and 60% from fat, consistently for at least 6 months were eligible for the LC group.
- The athletes consistently consuming >50% energy from carbohydrate were considered fro the HC group.

Volek et al, 2016, Metabolism, 100-110

Metabolic characteristics of keto-adapted ultra-endurance runners

Table 2 – Habitual daily nutrient intake.

	High-Carbohydrate Diet n = 10	Low-Carbohydrate Diet n = 10
	Mean ± SD	Mean ± SD
Energy, kcal	3174 ± 611	2884 ± 814
Protein, g	118 ± 38	139 ± 32
Protein, %en	14.4 ± 3.5	19.4 ± 2.4
Protein, g/kg	1.7 ± 0.4	2.1 ± 0.6
Carbohydrate, g	486 ± 128	82 ± 62
Carbohydrate, %en	59.1 ± 10.2	10.4 ± 4.9
Fat, g	91 ± 31	226 ± 66
Fat, %en	25.0 ± 7.4	69.5 ± 6.0
Saturated fat, g	21 ± 10	86 ± 22
Monounsaturated fat, g	29 ± 14	82 ± 42
Polyunsaturated fat, g	18 ± 9	28 ± 17
Alcohol, %en	1.6 ± 2.4	0.7 ± 1.4
Cholesterol, mg	251 ± 249	844 ± 351
Fiber, g	57 ± 27	23 ± 17

Volek et al, 2016, Metabolism, 100-110

Metabolic characteristics of keto-adapted ultra-endurance runners

- Participants of both groups performed a 180-minute submaximal run at 64% VO_2max on a treadmill. Heart rate and RPE were recorded every 30 min, and indirect calorimetry measurements were conducted at regular intervals.

- Prior to run participants consumed a shake (5kcal/kg body mass) with macronutrient distribution (% CHO: fat: protein) of 5:81:14 in the LC group and 50:36:14 in the HC group.

- After 180 min of running participants consumed a shake identical to pre-run shake and indirect calorimetry measurements were conducted 120 minute post exercise.

Volek et al, 2016, Metabolism, 100-110

Metabolic characteristics of keto-adapted ultra-endurance runners

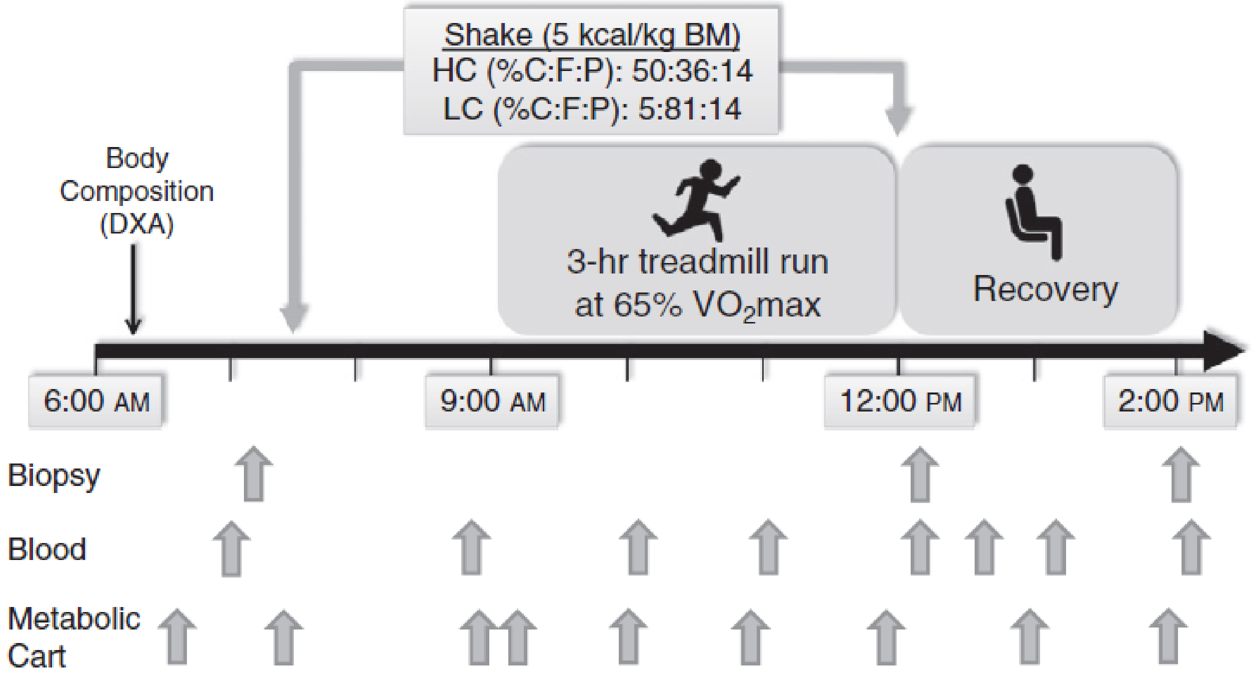
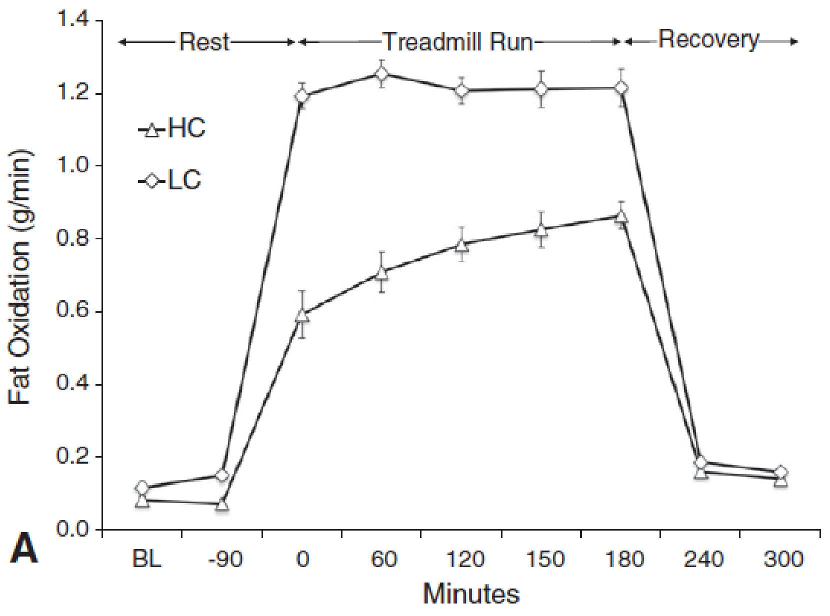


Fig. 1 – Experimental protocol to determine metabolic responses to submaximal exercise.

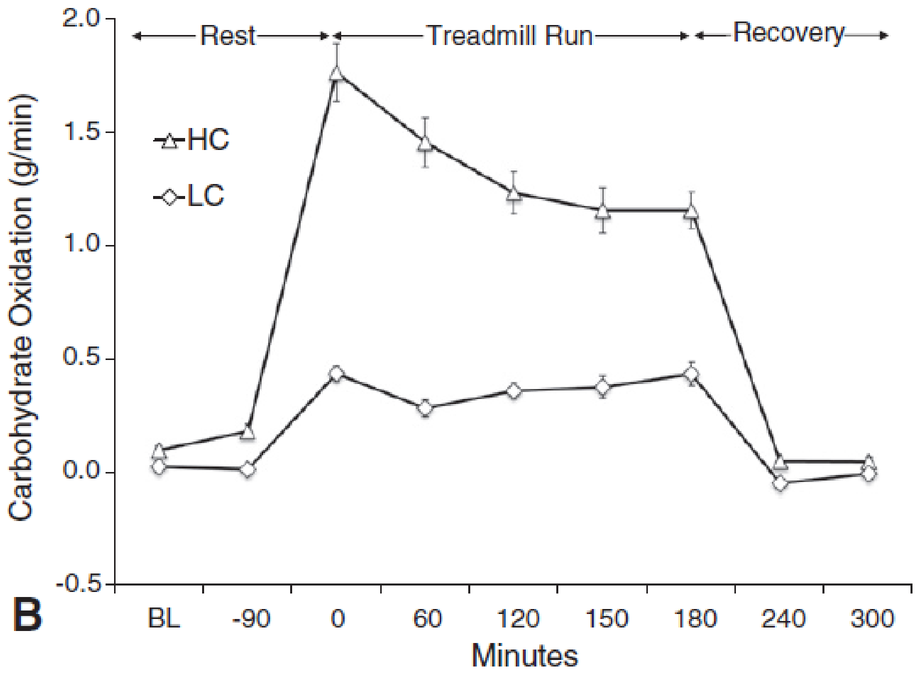
Volek et al, 2016, Metabolism, 100-110

Metabolic characteristics of keto-adapted ultra-endurance runners

Fat oxidation in athletes consuming high carbohydrate (HC) and low carbohydrate (LC) diet

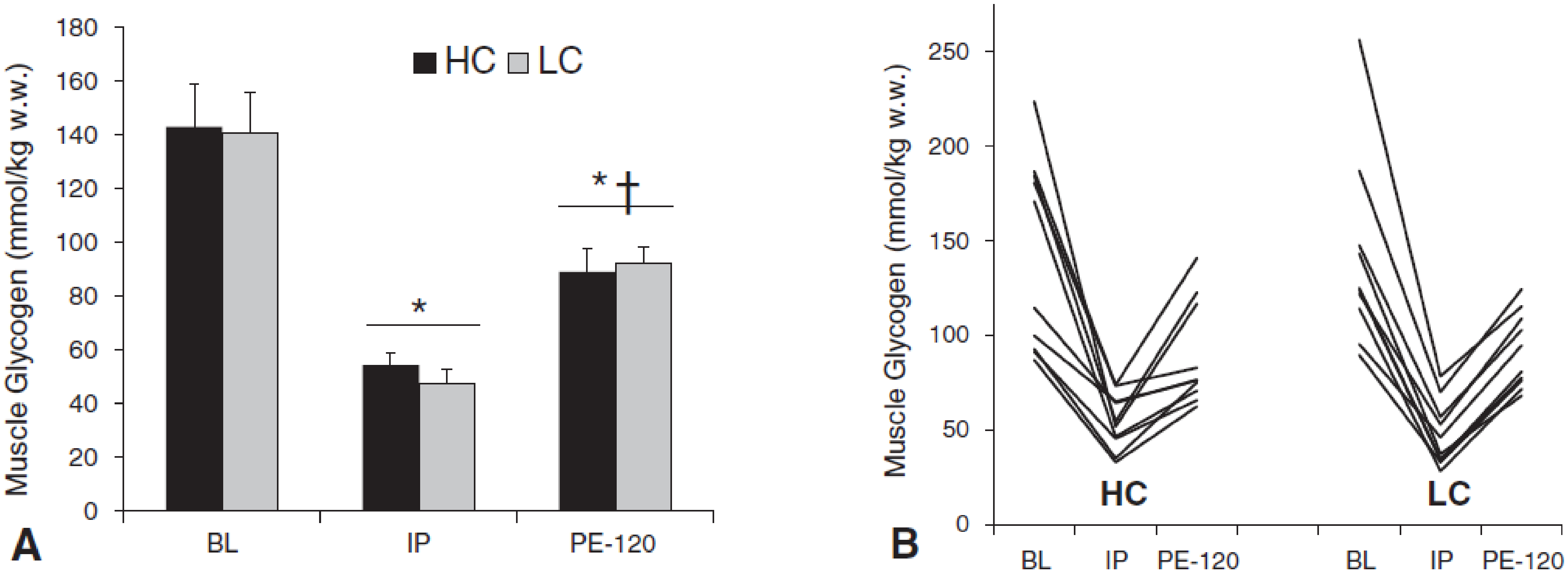


Carbohydrate oxidation in athletes consuming high carbohydrate (HC) and low carbohydrate (LC) diet



Volek et al, 2016, Metabolism, 100-110

Metabolic characteristics of keto-adapted ultra-endurance runners



Volek et al, 2016, Metabolism, 100-110

Metabolic characteristics of keto-adapted ultra-endurance runners

Main findings:

- Two-fold higher rate of fat oxidation during sustained submaximal running;
- No difference in pre-exercise muscle glycogen concentration;
- No difference in the rate of muscle glycogen utilization during exercise;
- No difference in the rate of muscle glycogen synthesis during recovery.

Volek et al, 2016, Metabolism, 100-110

Metabolic characteristics of keto-adapted ultra-endurance runners

Conclusion

Keto-adaptation in elite ultra-endurance athletes is associated with a robust capacity to increase fat oxidation during exercise while maintaining normal skeletal muscle glycogen concentration.

Volek et al, 2016, Metabolism, 100-110

Other Strategies to Attenuate Muscle Glycogen Depletion During Training and Competition

- Adaptations of skeletal muscle from endurance training.
- Carbohydrate intake during training and competition.
- Consideration of low GI meals while on of high CHO diets.
- Supplements increasing fat oxidation.

Carbohydrate intake during training and competition to spare glycogen stores

- For events lasting 1–2.5 h, 30–60 g/h is commonly recommended in a 6–8% CHO solution (concentrations typically found in commercial sports drinks) ideally consumed every 10–15 min to maximally spare glycogen stores.
- For events lasting >2.5 h, higher CHO intakes of 60–70 g/h, and up to 90 g/h if tolerable This higher intake recommendation stems from research demonstrating that exogenous CHO oxidation peaks at a CHO ingestion rate of 1.0–1.1 g/min, due to the maximal GI absorption at this rate
- Including multiple CHO sources (glucose/fructose mixtures) at higher ingestion rates of 1.8 g/min can further increase oxidation up to 1.2–1.3 g/min due to differential intestinal transport mechanisms, and these glucose/fructose combinations also improve GI tolerance,

Carbohydrate intake during training and competition to spare glycogen stores

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Key Recommendation for Macronutrient Intake (Exercise Duration in Italics within parentheses)

Nutrient	Daily Requirements	Pre-Exercise	During Exercise	Post-Exercise
Carbohydrate	5–7 g/kg/day *(1 h/day)* 6–10 g/kg/day *(1–3 h/day)* 8–12 g/kg/day *(4≥ h/day)*	6 g/kg/day *(<90 min)* 10–12 g/kg/day *(> 90 min)* + 1–4 g/kg (1–4 h prior to event)	30–60 g/h *(<2.5 h)* 60–70 g/h *(>2.5 h)* 90 g/h *(>2.5 h, if tolerable)*	8–10 g/kg/day (first 24 h) 1.0–1.2 g/kg/h (first 3–5 h) or 0.8 g/kg/h + protein (0.3 mg/kg/h) or caffeine (3 mg/kg)
Protein	1.4 g/kg/day 0.3 g/kg every 3–5 h	0.3 g/kg immediately prior (or post–exercise)	0.25 g/kg/h (if high intensity/eccentric exercise)	0.3 g/kg within 0–2 h (or pre-exercise)
Fat	Do not restrict to <20% total caloric energy Unclear role of CLA, omega-3, MCT supplements Consider limiting fat intake only during carbohydrate loading, or pre-race if GI comfort concerns			

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Carbohydrate intake during training and competition to spare glycogen stores

- At the higher ends of CHO intake, athletes should routinely practice intake plan to assess GI comfort (e.g., liquid CHO may be more tolerable than solid).

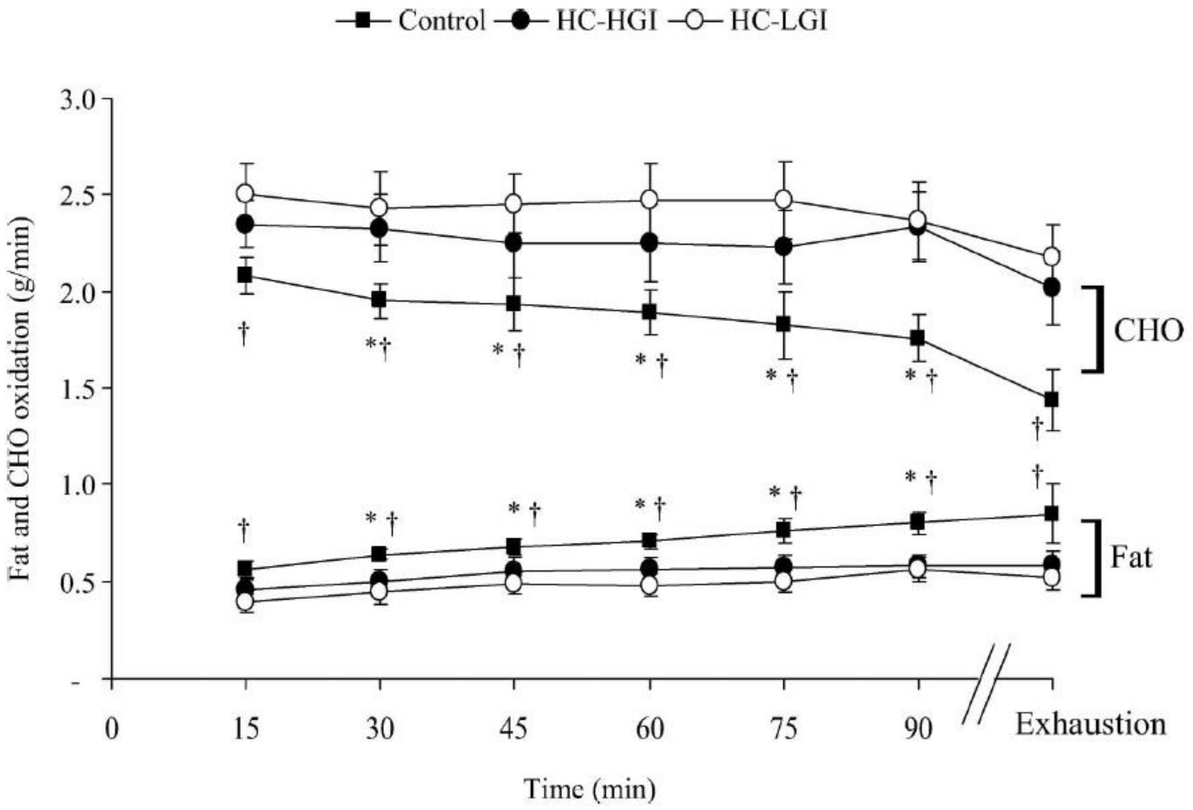
- CHO intake chances may vary according to rules of sport, e.g., halftimes during games, minimal/no fueling opportunity during swim portion of triathlon vs. ideal opportunity during bike, etc., and should be rehearsed.

- It is important to practice the fueling plan at race/game intensity, as GI tolerability can be decreased on race day due to the increased stress response.

- Athletes should reduce CHO intake by 10% in hot environments.

Effects of glycaemic index of high carbohydrate diets on fat and CHO oxidation metabolism during endurance exercise

<u>Hypothesis</u>: consideration of low glycaemic index (LGI) foods while consuming high carbohydrate (HC) diet allows better fat oxidation than consideration of high GI foods.



Hamzah et al, Journal of Sports Science, 2009, 27(14):1545-1554

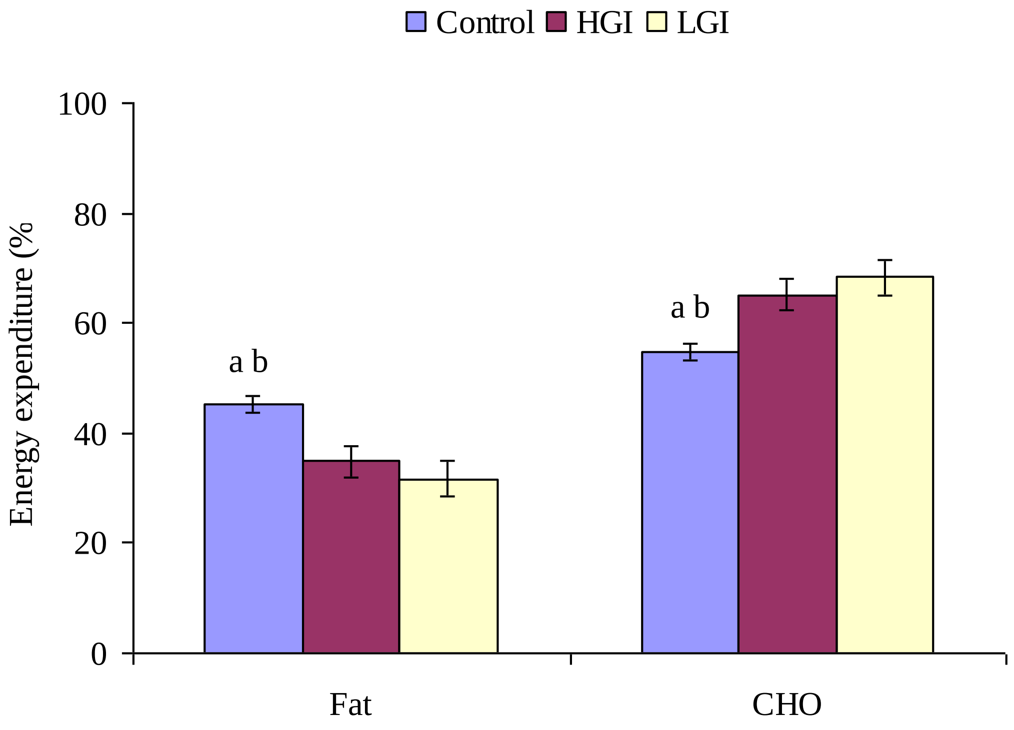
Effects of glycaemic index of high carbohydrate diets on fat and CHO oxidation metabolism during endurance exercise

Table I. Example of prescribed high carbohydrate/high glycaemic index (HC-HGI) and high carbohydrate/low glycaemic index (HC-LGI) meals consumed over 5 days.

Meal	HC-HGI	HC-LGI
Breakfast	Coco Pops™ breakfast cereal (100 g) + semi-skimmed milk (200 g), wholemeal bread (70 g) + jam (30 g) + low-fat spread (8 g), tea (260 g) + semi-skimmed milk (40 g)	All Bran™ breakfast cereal (100 g) + skimmed milk (200 g), Burgen® bread (70 g) + jam (30 g) + low-fat spread (8 g), tea (200 g) + semi-skimmed milk (40 g)
Snack	Apple (100 g), banana (100 g)	Pear (100 g), orange (100 g)
Lunch	Wholemeal bread (140 g) + lean ham (50 g) + low-fat spread (12 g) + cucumber (40 g) + tomatoes (40 g), Lucozade® original (340 g)	White pita bread (120 g) + lean ham (50 g) + low-fat spread (12 g) + cucumber (40 g) + tomatoes (40 g), lentil soup (400 g), unsweetened apple juice (340 g)
Snack	Rice cakes (30 g), Lucozade® original (330 g)	Cheese-flavoured oatcakes (30 g), unsweetened apple juice (330 g)
Evening meal	Instant potato (200 g) + peas (80 g) + chunks of chicken in gravy (300 g), Lucozade® original (330 g), bananas (100 g)	Pasta sauce (200 g) + mince meat in tomato sauce (200 g) + spaghetti (cooked weight 300 g), unsweetened apple juice (330 g), low-fat yogurt (200 g), orange (100 g)
Evening snack	Wholemeal bread (70 g) + low-fat spread (5 g) + jam (15 g), tea (260 g) + semi-skimmed milk (40 g)	Burgen® bread (70 g) + low-fat spread (5 g) + jam (15 g), tea (260 g) + semi-skimmed milk (40 g)

Hamzah et al, Journal of Sports Science, 2009, 27(14):1545-1554

The effects of glycaemic index of high carbohydrate diets on fat and CHO oxidation during endurance exercise



[a] Significantly different (P<0.05) from HC-HGI trial. [b] Significantly different (P<0.05) from HC-LGI trial.

Hamzah et al, Journal of Sports Science, 2009, 27(14):1545-1554

The effects of glycaemic index of high carbohydrate diets on fat and CHO oxidation during endurance exercise

Conclusions

- The extent by which a high carbohydrate diet consumed over 5 days reduced rate of fat oxidation during subsequent run at 65% of VO2 max in the fasted state is not influence by the glycaemic index of the diet
- The glycaemic index of high CHO diets had no impact on time to exhaustion and distance covered.
- From a practical perspective, these findings suggest that when high CHO diets are consumed for 3-5 days leading up to an endurance event, consideration of the glycaemic index in not necessary.

Hamzah et al, Journal of Sports Science, 2009, 27(14):1545-1554

Rational for increased Protein Intake during Endurance Exercise

- Exhaustive endurance exercise and significant eccentric activities e.g., marathons, downhill running, and obstacle course races can result in catabolism of muscle, especially in the setting of inadequate protein or reduced energy availability and leads to muscle damage.
- The athlete may therefore consider a pre-exercise dose of 0.3 g/kg protein and during endurance exercise approximately 0.25 g/kg protein per hour when taken along with carbohydrate is recommended to minimize potential muscle damage.
- Post-exercise protein added to carbohydrate can increase muscle glycogen synthesis if in the setting of suboptimal post-exercise carbohydrate intake (i.e., <1 g/kg/h), however will not further increase glycogen synthesis if the athlete already has high carbohydrate intake (>1.2 g/kg/h)

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Protein	1.4 g/kg/day 0.3 g/kg every 3–5 h	0.3 g/kg immediately prior (or post–exercise)	0.25 g/kg/h (if high intensity/eccentric exercise)	0.3 g/kg within 0–2 h (or pre-exercise)
Fat	Do not restrict to <20% total caloric energy Unclear role of CLA, omega-3, MCT supplements Consider limiting fat intake only during carbohydrate loading, or pre-race if GI comfort concerns			

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Recommended Protein Sources and Types

- Traditionally, proteins containing branched-chain amino acids (BCAAs leucine, isoleucine, and valine) have garnered much attention in both popular media and research.
- In recent years, protein with higher essential amino acids (EAA) and leucine content (700–3000 mg) have emerged to be the ideal source to stimulate muscle protein synthesis (MPS).
- Branched-chain amino acid supplementation still may help to prevent feelings of fatigue. However, BCAA supplements alone if not taken with EAAs may not adequately stimulate MPS.
- Dairy-based proteins (whey, casein and whole milk), lean meats, egg, and soy all stimulate MPS effectively However dairy-based proteins, particular liquid based, may be superior to other sources due to the higher leucine content and improved digestion/absorption kinetics.
- Athletes should be educated to consider EAA (which contain BCAA) protein sources rather than solely BCAA.

Jäger et al, J. Int. Soc. Sports Nutr. 2017;14:20.

Supplements for Endurance and Ultra-Endurance Athlete

- There are numerous supplements and strategies that may be employed by endurance athletes.
- Caffeine and nitrates are frequently investigated and used by athletes.
- Antioxidants and probiotics are commonly explored topics by injured athletes and are steadily-growing fields of research

Nutrients **2019**, *11*, 1289

Recommendations for Nitrates, Antioxidants, Caffeine, Probiotics

Nitrates	300–600 mg of nitrate (up to 10 mg/kg or 0.1 mmol/kg) or 500 mL beetroot juice or 3–6 whole beets within 90 min of exercise onset Consider multi-day dosing e.g., 6 days of a high-nitrate diet prior to event	
Antioxidants	Avoid prior to exercise to maximize training adaptation Take prior to exercise only if recovery needed within 24 h Many options: whole foods, dark berries, dark greens, green tea e.g., 8–12oz tart cherry juice twice a day (1oz if concentrate) 4–5 days prior and 2–3 days after event e.g., green tea extract (270–1200 mg/day)	
Caffeine	3–6 mg/kg taken 30–90 min prior to exercise Consider "topping-up" every 1–2 h as needed ≥9 mg/kg does not further enhance performance, may have undesirable side effects, + drug test ≤3 mg/kg can also be ergogenic without side effects	3 mg/kg with carbohydrate enhances glycogen repletion
Probiotics	*Lactobacillus* and *Bifidobacteria* may help with upper respiratory and/or GI symptoms	

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Recommendations for Water and Sodium Intake

Water	Try initial hydration plan at ~400–800 mL/h; Adjust according to individual athlete variations (sweat rates, sweat sodium content, exercise intensity, body temperature, ambient temperature, bodyweight, kidney function) Follow thirst mechanism, monitor parameters (bodyweight, urine color)	Replace fluid with 150% of fluid lost
Sodium	Try initial sodium plan at 300–600 mg/h if high sweat rate (>1.2 L/h), subjective "salty sweater," or prolonged exercise >2 h Adjust intake according to individual athlete variations (sweat rates, sweat sodium content, exercise intensity, body temperature, ambient temperature, bodyweight, kidney function)	Improved water repletion observed with >60 mmol/L sodium content (~1380 mg/L)

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Thank you

Any Questions?

Email: Dalia.Malkova@glasgow.ac.uk