compromised and to ensure optimal training capacity isn't disrupted. Easy ways to achieve this are to minimise alcohol intake, and restrict total dietary fat intake. For muscle mass gain, add an additional 1000–2000 kJ/d onto your energy requirement. To fulfill remaining energy requirements, include a balance of additional protein, carbohydrate, and dietary fat, taking care to ensure that all micronutrient requirements are adequately met.

3 Carbohydrate intake during exercise: when, what and how much?

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The benefits of carbohydrate ingestion during exercise are well described. So, the obvious question is how the supply of carbohydrates can be optimized. Although dose-response studies have not been conclusive there is some emerging evidence that high oxidation rates of the carbohydrate can be beneficial in some situations (Table). This will require the ingestion of fairly large amounts of carbohydrate, which in itself could be linked to gastro-intestinal problems. Combinations of carbohydrates (for example glucose and fructose) ingested at high rates seem to minimize the negative side effects and optimize carbohydrate delivery.

EVENT	CHOICE OF CARBOHYDRATE			
	Energy expenditure	Carbohydrate required for optimal performance and minimizing negative energy balance	Recommended intake	carbohydrate type
Exercise of < 45 min duration	>18 kcal/min	No CHO required	•	•
Exercise of 1 h duration	14–18 kcal/min	Very small amounts of CHO	•	•
Exercise > 2 h Low to moderate intensity	5–7 kcal/min	Small amounts of CHO	Up to 30 g/h	Can be achieved with most forms of CHO
Exercise > 2 h Moderate to high intensity	7–10 kcal/min	Moderate amounts of CHO	Up to 60 g/h	Can be achieved with CHO that are rapidly oxidized
Exercise > 3 h, Ironman, Tour de France stage races	10–14 kcal/min	Large amounts of CHO	Up to 90 g/h	Can only be achieved by intakes of multiple transportable CHO

Strategies to take carbohydrate on board

When

Carbohydrate ingestion can enhance performance during exercise of 45 min or longer. So if the quality of a training session is important or in competition, consuming some form of carbohydrate will help.

What

The type of carbohydrate has considerable impact on the speed of energy delivery. Some carbohydrates are oxidized at higher rates than others. However, a combination of maltodextrins and fructose, glucose and fructose, glucose, sucrose and fructose seems to result in the highest oxidation rates.

How

How the carbohydrate is ingested and in what form seems to be less important for the delivery of carbohydrate but can be important for fluid delivery. Highly concentrated carbohydrate solutions can impair fluid delivery. It is generally recommend to ingest a certaion volume at the start to prime the stomach and to keep topping this up with smaller boluses at regular intervals.

How much

How much you ingest depends on a number of factors including:
1) What type of exercise (intensity and duration; see Table).
2) The type of carbohydrate (or combination of carbohydrates).
3) Tolderance. Especially this factor is highly individually determined and only practicing in training (and competition) will help an individual find out what will work for them.

Suggested additional resources

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4 Optimising training adaptations by manipulating glycogen

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The recent discovery that training in a low glycogen state may have benefits on the adaptive response to endurance exercise suggests that this may be another training tool that can be used to optimize performance.

However, since high glycogen levels are an important determinant of endurance performance, maintaining low glycogen throughout training may prevent an athlete from maintaining the training intensity required to attain maximal performance. Further, in motor/strength endurance activities, such as rowing, cycling, and swimming, where muscle strength is an important determinant of performance, the benefits of low glycogen are potentially outweighed by the need to maintain or increase muscle mass.

As a result, the preliminary suggestions for glycogen levels during training (Table) reflect the different goals and phases of training. While the incorporation of glycogen manipulation seems promising, the definitive studies on endurance performance still have not been done.

Stage of Training	Optimal Glycogen State	
	Strut Endurance	Motor Endurance
Phase I (base)	**Goal:** Increase endurance and add miles **Glycogen:** Low to maximize aerobic adaptations	**Goal:** Increase strength and maintain endurance **Glycogen:** High to promote gains in muscle mass
Phase II (build up)	**Goal:** Prepare the body for increased speed with short speed workouts while maintaining high mileage **Glycogen:** High before speed work, Low at other times	**Goal:** Build endurance with long distance work while maintaining strength **Glycogen:** Endurance training early in the day following a low CHO meal to keep glycogen low. Strength late in the day after replenishing glycogen
Phase III (consolidation)	**Goal:** High quality workouts including long speed workouts while decreasing mileage **Glycogen:** High in the morning before speed work, incorporating a second run in a low glycogen state 2–3 times per week	**Goal:** High quality, high speed training supplemented with low speed training to promote recovery and maintain endurance **Glycogen:** High before speed work, incorporating a second session in a low glycogen state
Phase IV (competition)	**Goal:** Maximal performance **Glycogen:** High	**Goal:** Maximal performance **Glycogen:** High
Phase V (recovery)	**Goal:** Rest and Recover **Glycogen:** High	**Goal:** Rest and Recover **Glycogen:** High

Strategies for manipulating glycogen

When

It is best to use low glycogen training during periods where the primary goal of training is to increase endurance capacity and maximize adaptations such as muscle mitochondria. At times when "quality training" i.e. training at or above lactate threshold, the positive effects of high glycogen on intensity and recovery likely outweigh the potential benefits of low glycogen on mitochondrial adaptations.

What constitutes low glycogen

The positive effects of training with low glycogen were seen in subjects that trained with glycogen levels one third that of the glycogen supercompensated state. This works out to the level of glycogen within a muscle that has been exercised at 75 % of max for one hour.

How

Training with low glycogen can be achieved in a number of ways. The first is by using multiple training sessions within a single day either without consuming any calories or having a low CHO meal in between sessions. The second way is manipulate the diet to maintain a chronically lower glycogen level by replacing CHO in the diet with greater proportions of fat and protein. Interestingly, low intensity training on a high fat diet has been shown to induce more mitochondrial adaptations than the equivalent training on a CHO rich diet.

How much

Using glycogen-depletion training by incorporating a second low-intensity session following a fast even a few times a week may have benefits on performance. As with all training techniques, each athlete will have to determine whether training with low glycogen affects their recovery and therefore the overall intensity of their training.

Suggested additional resources

1. Akerstrom, T. C., Birk, J. B., Klein, D. K., Erikstrup, C., Plomgaard, P., Pedersen, B. K., et al. (2006). Oral glucose ingestion attenuates exercise-induced activation of 5'-AMP-activated protein kinase in human skeletal muscle. Biochem Biophys Res Commun, 342(3), 949-955.
2. Hansen, A. K., Fischer, C. P., Plomgaard, P., Andersen, J. L., Saltin, B., & Pedersen, B. K. (2005). Skeletal muscle adaptation: training twice every second day vs. training once daily. J Appl Physiol, 98(1), 93-99.
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