Nutritional and Fluid Intake in Cross Country skiing

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Nutritional advice for endurance athletes

Main principles of good nutrition

At present, both general nutritional information and sport specific guidelines are readily available in numerous books of all sizes. “Nutrition in Sport”, edited by R. Maughan, is a new book in the IOC Medical Commission publication series that is highly recommendable for acquiring more in-depth knowledge in the field. Nevertheless, ignoring the risk of producing mostly banalities and oversimplifications, this section will attempt to present some basic nutritional information related to endurance sports like cross-country skiing. The target group is therefore skiers, coaches, and medical staff with limited previous knowledge in this area. The most essential issues of nutrition for athletes may be summarized in the following principles:

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Main principles of good nutrition

1. Eat enough food to compensate for training-induced energy expenditures

2. Eat high quality food rich in vitamins and minerals

3. Eat a wide variety of foods

4. Eat foods with high carbohydrate content

5. Eat a minimum of 3-4 meals per day, depending on training volume
1. Eat enough food

In an endurance sport like cross-country skiing where large groups of muscles are used -- often over several hours each day -- it is imperative that the athlete re-supplies the body with adequate amounts calories to balance the large expenditures during training. Energy turnovers as large as 20 MJ \cdot day^{-1} (megajouls per day) in females and 35 MJ \cdot day^{-1} in males were measured in Swedish national team cross-country skiers during an altitude training camp. Some of the skiers had serious problems consuming enough food to compensate for these huge energy expenditures. However, over a one-week period, which included a day of reduced training, the athletes were able to eat enough to reach caloric balance. Therefore, it is important to be aware of the caloric deficit that may develop during intensive training periods and also try to eat well on days with less or no training.

Body weight measurements are not a sensitive method for monitoring short-term changes in caloric balance, since it does not discriminate between changes in food/caloric intake and liquid/non-caloric intake. In other words, if you burn 1 kg of fat and carbohydrates and replace it with 1 l of water, your pre exercise body weight is regained, but you have a caloric deficit that will reduce the efficiency of reloading your energy stores for the next days’ training sessions. However, if measured in the morning over a longer period of time, body weight may be a good indication of the overall balance between total energy expenditure and intake. The volume of food that an athlete needs to consume to keep a caloric balance during periods with large training loads may present a problem because it requires the athletes to eat more than they want. During these periods, increasing the fat content of the food somewhat could reduce this problem, since the number of calories stored in for example 100 g of fat is almost 4 times as many as in 100 g of carbohydrate.
2. Eat high quality foods

In addition to adequate caloric consumption, the body also needs high quality food and not just “empty” calories from plain fats or sugars. In simple terms, it is vital to be concerned with both *quantity* and *quality* of foods. A variety of proteins, fats, and carbohydrates from various food sources are necessary to build the many tissues of the body, and supply the body with the best energy for physical performance. The term “high quality foods” is not easily defined, but includes some of the characteristics listed below:

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**High quality food characteristics:**

Foods that are *fresh* -- like vegetables, fruits and berries  
Foods that contain a *variety of nutrients* -- like dark bread, fish and light meat  
Foods that are *not manipulated* -- like meat from hormone treated animals  
Foods that are *not overly processed* or overcooked before eaten -- like ”TV dinners”  
Foods that are grown in rich soil and *not contaminated* with chemicals and pollution

In addition to the concerns regarding the quality of macronutrients in the food, (i.e. fats, proteins and carbohydrates), the micronutrient content (i.e. vitamins, minerals, and trace elements) is also very important to optimal health and sports performance. Potato chips and chocolate may be good sources for plain calories, but they supply very few of the vitamins, minerals, and trace elements. These micronutrients are needed to keep vital metabolic processes going in the immune system, the muscles, or any other functional unit of the body.
The amount of vitamins, minerals and trace elements that we get through various foods are not only dependent on the quality of each original food product (i.e. a tomato or fish filet), but also on the way the food source is processed into a particular product (i.e. a pizza or fish soup) and treated before eaten. In very general terms, the more the food is processed and cooked before appearing on the plate, the fewer vitamins, minerals and trace elements will be preserved. Therefore, athletes need to be conscious about what type of food to select and how to prepare the food for meals, in order to get an optimal content of both macro- and micronutrients in your food. This is particularly important to athletes who need to replace large amounts of nutrients every day. The pre-made “TV-dinner” or “poor mans pizza” from the freezer might not give the competitive edge in a major ski championship!

It should be mentioned that the recommended daily intake (RDA-levels) of various vitamins, minerals and trace elements might differ somewhat between countries. Moreover, these RDA-levels are based on a minimum intake of each substance that should prevent malnutrition and illnesses in the general population. Athletes with substantial energy expenditure may be in need of larger quantities of vitamins, minerals and trace elements than the national RDA levels. However, an increased micronutrient intake is normally secured through larger amounts of high quality food products among endurance athletes.

3. Eat a wide variety of foods

In order to secure sufficient intake of micronutrients, athletes also have to be concerned with the variety of food in their daily diet. Vitamins, minerals, and trace elements are found in large concentrations in some food sources, but in minimal quantities in others. Some of these substances are bound to water molecules in the food while others are bound to fat molecules. Therefore, a good combination and balance of all major food sources like dairy products,
bread, cereals, fruits, vegetables, rice, pasta, potatoes, meat, fish and other seafoods etc.
should be included. Since most of the micronutrients are not produced by the body itself, the
availability of these substances for metabolic purposes rely on a steady and balanced intake
through the diet.

Selecting a wide variety of foods is not only important for the micronutrient intake. It is also
critical in order to achieve a good balance of the macronutrient intake, i.e. carbohydrates,
proteins, and fats. There are a great number of different carbohydrates, proteins, and fats in
the various food products. The body needs many of these individual substances either pre-
fabricated or in the original form, and because it cannot synthesis them by itself, the dietary
intake becomes paramount. Regarding the overall distribution of carbohydrates, proteins and
fats in the diet of an athlete, sports nutritionists recommend between 60-65% of the daily
energy intake come from carbohydrates, 12-15% from proteins, and 25-30% from fat. Only a
five to seven days meticulous recording of all food and liquid intake can ultimately determine
if the athletes’ diets comply with this guideline. However, it has consistently been found that
if a careful selection and combination of the basic food products mentioned above is used --
and a healthy dinner is included every day -- the recommended percentages of carbohydrates,
fats and proteins are most always achieved. Nevertheless, it may be a good strategy to have
the nutritional habits of all new skiers on a team evaluated by a sports/ clinical nutritionist.
Then, if the initial screening reveals nutritional concerns of some kind, a dietary registration
should be completed and proper nutritional interventions made as soon as possible.

4. Eat foods with high carbohydrate content

The intake of carbohydrates recommended for athletes is somewhat higher than the national
guidelines for the normal population, because carbohydrates are very important fuel sources
during exercise of moderate to high intensity. Perhaps more importantly, the carbohydrate (i.e. glycogen) may be emptied after only two hours of strenuous exercise. Fat is also an important fuel, particularly during low and moderate intensity exercise, but the fat stores last much longer than the stores for carbohydrates. In order to reload the glycogen stores after strenuous exercise, it is of great importance to eat enough food that is rich in carbohydrates. However, the athletes should know that there are different types of carbohydrates, from simple sugars like glucose and fructose to complex sugars like starch. A sufficient mix of the various carbohydrates is vital to athletic performance, with an emphasis on simple sugars (sources 1-4) during and immediately following exercise, while the more complex sugars (sources 5-6) should be consumed during meals. Simple sugars are rapidly absorbed from the gut into the blood circulation, (i.e. a high glycemic index) and thus readily available as energy for the working muscles. Conversely, foods with complex sugars have a slower rate of absorption from the gut and thus less effective as an instant energy source, (i.e. a low glycemic index). However, the energy in the complex sugar molecules are densely packed and within a few hours after a post-exercise meal will result in effective restoration of the glycogen stores both in muscle and liver.

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Some common sources for carbohydrates

1. Sports drinks and lemonades
2. Chocolate and ice-cream
3. Sweet cookies, rolls muffins and biscuits
4. Fruits and fruit-juices, grapes/raisins and berries
5. Cereals and bread
6. Pasta, rice and potatoes
Having underlined the special concern for plenty of carbohydrates in the athlete’s diet, it must not be forgotten that proteins are also important nutrients for a cross-country skier who enforces prolonged metabolic stress on large masses of muscles. Milk, cheese, eggs, meat, fish, pies, beans, etc are good sources for dietary proteins. In fact, there is some indication of increased effectiveness in restoring glycogen in muscle after prolonged exercise if proteins are consumed in addition to carbohydrates during the first hours post-exercise.

Picture: Ch3-sD-P1

### 5. Eat a minimum of four meals pr day

There is no ideal number of meals pr day for an athlete, but no meals should be separated by more than 5-6 h during the day. The total energy intake could be divided into a minimum of three meals pr day, with a couple of snacks before and after practices or five meals with no extra snacks. A “middle of the road” alternative may be recommended with four regular meals -- each separated by about four hours and one snack (cheese-sandwich, energy bar, fruits, etc) -- right after practice. If the athlete has two training sessions per day, effective reloading of muscle glycogen between the two sessions is imperative. An extra snack -- preferably immediately after the first session -- should therefore be included in addition to a regular lunch or afternoon meal.

**Nutritional supplements**

Use of nutritional supplements in most sports has increased extensively the last two decades. A recent study showed that 95% of the members on the Norwegian national cross-country and Nordic combined ski teams used one or more dietary supplement-- even if all carbohydrate supplements were excluded. This was observed in spite of the fact that 94% of the skiers reported adequate nutritional habits. The reason for taking extra vitamins, minerals, trace
elements, dietary fatty acids etc, may vary considerably. It may be based on medical indications, for example as part of diagnosing low iron stores or calcium deficiency in a young female athlete. However, in most instances the supplementation takes place for a number of non-medical reasons ranging from improved general health and recovery after training sessions to unsubstantiated claims of enhanced performance.

Picture: Ch3-sB-P2

For several purposes it is impossible to establish a “consensus statement” on if, when and what nutritional supplements should be used for an endurance athlete. From a scientific and medical point of view, if good nutritional habits are followed and no deficiencies are disclosed, there is no need for dietary supplements. Nevertheless, there may be situations where supplements could be considered, particularly if nutritional interventions are hard to make.

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Nutritional supplements may be considered in the following situations:

1. Periods of low caloric intake
2. Periods of weight reduction
3. Periods with little variance in the diet
4. A diet without essential foods like fish, dairy products, grains etc.
5. Change to vegetarian or vegan diet
6. Large menstruation bleedings
7. Periods of heavy training, particularly at high altitude
8. Periods of frequent respiratory infections

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There is some scientific support for a general recommendation of vitamin C supplementation to athletes, particularly during periods of hard training and competitions or altitude training. However, the amount of vitamin C (400-800 mg daily) could very well be covered by additional fruits and juices in the normal diet. Although there is evidence of free radical involvement in exercise-induced muscle injury, vitamin E supplementation might not be expected to prevent muscle damage caused by exercise in humans without a vitamin E deficiency. Since it is still unclear whether exercise induces lipid peroxidation in the human body, the beneficial effect of vitamin E supplementation has not yet been fully established. Nevertheless, some scientists advocate a moderate dose of 100 to 200mg vitamin E daily for endurance athletes during periods of hard training and competitions or altitude training to reduce possible exercise-induced oxidative damage. Sufficient iron intake is also a special concern for young female athletes and for all skiers using altitude training. If iron stores are low before going to altitude camps, the expected increase in red blood cells and aerobic capacity may be eliminated. Therefore, ferritin values should be checked in due time to correct potential or evident iron deficiencies (ferritin < 30 mmol/l in males and <25 mmol/l in females) before training at altitude above 1800 m.

A general warning on the use of nutritional supplements should be issued both for the purpose of not overdosing any of the micro-nutrients and because of potential conflicts with banned substances. Any commercially produced supplement carry a risk of being mixed or contaminated with banned substances on the IOC list. Even though this risk may be minimal for regular vitamin and mineral supplements produced under GMP (Good Manufacturing Production) standards, it can never be eliminated. A particular warning should be added towards supplements marketed with strong -- but often unsubstantiated -- claims of improved health, body composition and/or performance. These products may deliberately be
mixed with banned substances -- like anabolic steroids or ephedrine that are known to have performance enhancing effects-- without being identified on the product label.

Consult the chapter “Immune function, exercise and infection” for further discussion on the effect of nutritional supplementation on exercise-induced immuno-suppression.
Summary

1. Main principles of good sports nutrition for endurance athletes are: a) eat enough food over 3-5 meals pr day to compensate for energy expenditure in training b) eat a wide selection of high quality food rich in vitamins and minerals c) eat foods with high carbohydrate content after each training session

2. Energy turnovers as large as 20 MJ \cdot \text{day}^{-1} for female and 35 MJ \cdot \text{day}^{-1} for males cross-country skiers have been measured. Increasing the fat content of the diet temporarily can reduce the risk of caloric deficits during intensive training periods

3. A variety of proteins, fats, and carbohydrates from various high quality food sources is necessary to (re-) build the many tissues of the body, and provide the best energy for physical performance

4. It is recommend that endurance athletes should have 60-65% of the daily energy intake from carbohydrates, 12-15% from proteins, and 25-30% from fat.

5. Daily intake of a balanced diet with major food sources like dairy products, bread, cereals, fruits, vegetables, rice, pasta, potatoes, meat, fish and other seafoods will normally secure a sufficient intake of most micronutrients.

6. In order to reload the glycogen stores after strenuous exercise, it is importance to eat enough food that are rich in various carbohydrates with an emphasis on simple sugars (sources 1-4) during and immediately following exercise, while the more complex sugars (sources 5-6) should be consumed during meals

7. Increased effectiveness in restoring glycogen in muscle after prolonged exercise may be achieved if protein rich foods like milk, cheese, eggs, meat, fish, pies, beans, etc are consumed in addition to carbohydrates during the first hours post-exercise

8. Nutritional supplements may be considered during periods of a) low caloric intake, b) planed weight reduction, c) little variance in the diet, d) lack of essential foods
sources, e) change to vegetarian or vegan diet, f) large menstruation bleedings g) frequent respiratory infections h) periods of large volumes of training, particularly at high altitude

9. A general warning on the use of nutritional supplements should be issued both for the purpose of not overdosing any of the micro-nutrients and because of potential conflicts with banned substances
**Suggested readings**


Figure legends: "Nutritional advice for endurance athletes"

Ch3-sD-P1

There is a close connection between good nutritional habits and performance in endurance sports. A sufficient caloric intake and a wide selection of food sources form the basis for optimal recovery from training and preparation for cross-country races.

Ch3-sD-P2

When training and competing at moderate or high altitude, cross-country skiers should check their nutritional status and particularly their iron stores (ferritin levels). Supplementation with certain vitamins and minerals should be evaluated on the basis of actual intake and estimated turnover of all micronutrients. Supplementing high doses of certain vitamins and minerals may be harmful and should be avoided.
Carbohydrate loading and fluid replacement

Energy sources in exercise

Carbohydrates and fats and are both important fuels for working muscles. However, they contribute differently to the total energy turnover during exercise, depending on intensity and duration of the exercise. Despite the fact that the body has much more energy stored as fat compared to glycogen (ca 390.000 kJ as fat vs 7.500 kJ as carbohydrates in a 70 kg man), there is a definite limit to how much fat fuels can contribute to increased work output during high intensity exercise.

Fig 1: Energy sources at different exercise intensities/ VO$_2$ max. NB: Need a figure!!

Fat fuels -- mainly in the form of free fatty acids – are the major energy sources for low intensity exercise (i.e. 25-50% of VO$_2$ max). As the work intensity is increased, a proportionally greater amount of carbohydrate (primarily stored as glycogen) compared to fat will be used in the working muscle. At intensities above 50-60 % of VO$_2$ max, carbohydrates takes over as the primary energy source. If the work intensity is increased even further, almost all the energy has to come from carbohydrates. This is supplied from glycogen stores in muscle and liver, or from glucose molecules in the blood supplied by carbohydrate drinks (or foods) consumed while exercising. Since there is a limit to how much glycogen that can be stored in the body before exercise, a shortage of this fuel will develop after ca 90 min of high intensity exercise (Fig 3: Muscle glycogen vs exercise duration). Not surprisingly, this progressive limitation of carbohydrate supply within the working muscle will lead to a decrease in performance, even before the fuel is totally gone.
When glycogen stores are completely empty, a drastic decline in performance is seen. This is of course a situation that any endurance athlete wants to avoid. Theoretically, there are three potential strategies to limit the problem of fuel shortage during prolonged strenuous exercise: 1) increase the capability of storing glycogen in muscle before exercise/race, 2) increase the supply of carbohydrate to the working muscles during exercise/race, 3) increase the fat utilization during exercise.

Fig 2: Changes in energy sources during prolonged strenuous exercise (Use fig 2.9 in Nutrition and Sports, Ed: R.J. Maughan)

**Strategies of carbohydrate loading**

The first strategy has been called “glycogen super-compensation”. Several scientific studies have been able to show increased levels of glycogen in muscles after two different regimes of dietary intake and exercise protocols over several days. In the classical regime, the athletes completed an exhaustive bout of exercise nine days prior to a race to deplete their glycogen stores and thereafter consumed a high protein and high fat diet the following three days. A new exhaustive bout of exercise was completed on day five prior to the race, but now followed by three days on a high carbohydrate diet. A 100% increase above the initial muscle glycogen concentration was demonstrated with this regime. In another less complicated regime, the athletes ran at 75% of VO$_2$ max for 90 min, 40 min, 40 min, 20 min, 20 min over a six-day period and then rested the last day. When consuming a diet with 50% carbohydrate the first three days, followed by a diet with 75% carbohydrate the last three days, these athletes also increased their glycogen stores ca 100% above initial level. In conclusion, both the classical and the modified regimes seems to be effective in elevating
glycogen stores to “supra-normal” levels, but the modified regime --which do not include two exhaustive exercise sessions-- has easier diet routines and lasts only six days.

**Carbohydrate turnover**

Even though the phenomenon of glycogen super-compensation has been demonstrated, there is very limited scientific data suggesting that it will result in enhanced performance in a race. However, plenty of research has demonstrated that intake of carbohydrates during prolonged strenuous exercise has a performance enhancing effect. The following facts should explain this matter.

The efficacy of fuel utilization (i.e. oxidation of fat and carbohydrate) in the muscles determines the amount of energy that can be produced per minute. The speed by which fat and carbohydrate can be utilized in the tissue is called the oxidation rate. There is a limit to how fast the fuel can be used in each muscle cell and subsequently how fast energy can be created. This upper limit is called “maximum rate of oxidation” and for carbohydrates the maximal level is about 1.0-1.3 g/min. This means that the muscles cannot burn more than 1g of carbohydrates in 1 min, and therefore not create additional energy, even though the muscles were supplied more than 1.3 g of carbohydrate/min. As long as this amount of carbohydrates can be provided from glycogen stores in the muscle itself or from the liver, the maximum oxidation rate is achieved and generation of energy from the muscles is sustained. However, when glycogen stores are limited or emptied during prolonged strenuous exercise, exogenous supply of carbohydrates becomes increasingly important to support a maximum oxidation rate and energy output in the muscles. After ca 90-100 min at race speed, carbohydrates from drinks and food turn out to be the main source of carbohydrate supply. Consequently, ingesting carbohydrates during the latter part of a long distance race or exercise is imperative to uphold a high work load, but the rate of absorption
from the gut seems to be a “bottle neck” in providing the muscles with enough carbohydrate fuels. Several factors may account for the limitation of carbohydrate uptake from the gut to the blood and it seems that ingesting carbohydrates at a rate of 60-80 g/hour (1.0-1.2 L/hour of a 6% carbohydrate solution) is the upper limit of what can be absorbed from the gut. Exercise training may increase the muscle’s ability to use more fat relative to carbohydrates at a certain power output or percentage of VO\textsubscript{2} max, but the maximum rate of oxidation is fairly constant and not subject to improvement by exercise training.

Based on these scientific facts, it is quite obvious that supplying the muscles with carbohydrate fuels both before and during strenuous exercise is vital to keep a constant high speed in any endurance sport. It also explains why supplying more carbohydrate energy than the muscles can burn at maximum rate of oxidation will not result in a higher power output and therefore not increased physical performance. Exemplifying this by using the analogy to a car might clarify this matter: If the engine has a limit to how much fuel it can burn per minute, neither storing more fuel by increasing the gas tank, nor flooding the carburetor with too much gas while the engine is running, will increase the maximum speed of the vehicle. However, by making sure the glycogen “tank” is completely full before a race and by making short “pit-stops” for adequate carbohydrate “refills”, athletes will endure longer at a higher intensity of exercise.

**Practical implications**

In preparations for a long distance race, the last meal should be completed at least three hours before start. Foods rich in carbohydrates --such as bread, oatmeal porridge or cereals for breakfast or rice, pasta, and potatoes for lunch-- is recommended. However, some easily digestible fat and protein sources – like cheese, omelet, ham, salami, or white meat – is also needed. The most important thing is to be able to supply adequate amounts of high quality
foods without causing disturbances to the gastro-intestinal tract. A pre-competition meal
should therefore be tested out before a strenuous bout of exercise prior to a race.

Intake of carbohydrate drinks and foods during the last three hours before start was
previously discouraged because it could increase the blood sugar regulating hormone insulin
and causes a subsequent decrease in blood glucose concentrations. However, unless larger
meals or volumes of sweet drinks are consumed in the hours immediately before the race, or
an athlete is particularly sensitivity to insulin changes, the alterations in blood sugar levels
will be minimal and not present a problem to the athlete. If preparing for a race of more than
80-90 min duration, small portions of carbohydrates should be consumed every 15-30 min
during the last 3h before the race. A sandwich and a banana or a muffin and a cookie may
serve this purpose, but during the last hour before start, carbohydrate-electrolyte drinks are
preferable. Immediately before the ski race, 200-400 ml of a 6-8% carbohydrate solution
may be consumed without any detrimental effect on insulin and blood glucose
concentrations. Gastro-intestinal tolerance and instant need for urination must of course be
controlled. Therefore, this strategy needs to be tested out in a prior training session before
applied in a race setting. To achieve optimal availability of the carbohydrates to the muscle,
a combination of two or more types of carbohydrates, (i.e. glucose, sucrose, and
maltodextrins) in a drink may be advantageous. Furthermore, a near isotonic solution of the
carbohydrates along with the addition of some salts/electrolytes will improve the
gastrointestinal absorption and thus the availability of the carbohydrates during exercise.

Picture: Ch3-sE-P1

During a long distance ski race, ingesting 50-80 g of carbohydrate pr hour, (ca 800-1200 ml
of a 6-7% carbohydrate solution), should result in sufficient intake of carbohydrates to
maintain adequate supply for working muscles. However if skiing at high intensities, the carbohydrate intake during the race can never fully compensate for the steady decline in the body’s glycogen stores and thus avoid energy shortage after ca two hours. But, carbohydrate intake -- particularly during the early part of a race -- will reduce the utilization both fat and glycogen from the muscles, thereby saving these energy sources for later stages. A steady intake of 150-200 ml of a 6-8% carbohydrate-electrolyte solution every 10-15 min --already from the first hour of a race -- is recommended.

**Fluid loss during endurance exercise**

Having emphasized the need for carbohydrate fuel –before and during endurance exercise-- it must not be forgotten that fluid intake is as important as energy intake for optimal performance. Fluid loss is dependent on both exercise intensity and modality, plus a number of environmental factors such as ambient temperature, air humidity, wind, direct radiation from the sun, clothing etc. Intense exercise on warm days --even during winter-- may result in fluid loss of more than 1000 ml pr hour. Fluid loss resulting in more than 1,5 - 2% loss of body weight will affect performance. For a 75 kg person that is equivalent to 1200-1500 ml, and in a race fluid loss may have negative impact on performance already after 50-60 min.

The main reason for decrement in performance is that dehydration of this magnitude leads to a reduction in blood volume with subsequently reduced stroke volume. The result is decreased blood flow through the muscles, which ultimately reduces oxygen supply and metabolic clearance.

This means that the fluid intake must be carefully planed and executed during long distance races. In many situations during long distance cross-country skiing, fluid loss may be a larger concern than energy deficits. However, fluid intake of more than 700-800 ml pr hour during a ski race may present practical problems for the skiers without interfering with their
performance. In preparations for such events it is important to practice drinking larger volumes of fluid during training to make the gastro-intestinal system tolerate fluid intake during strenuous exercise. Strategic planning of “drinking stations” on the race course may also alleviate some of the problems with sufficient fluid intake during competitions.

In elite cross country skiing competitions, carbohydrate and fluid replacement has normally been practiced only in the 30 km race for women and 50 km races for men. Depending somewhat on the terrain of the racetracks, most teams will serve 150-200 ml every 4-5 km, which means every 10-15 min at race speed. An estimate of the actual intake during a race was done in the Holmenkollen 50 km classical World Cup race. The 10 best Norwegian skiers consumed a total of 1200-1600 ml during the 130-140 min race, but this was only 60-70 % of the total volume served. This high waist percentage is probably not uncommon. Even though liquid consumption was not measured during this race, the fluid intake must have been far from matching fluid loss during this 50 km race. Thus, moderate dehydration was evident, despite good efforts to avoid this during the race. Traditionally, fluid replacement has not been practiced during the 30 km race for men -- with a normal race time between 65-80 min -- because major energy and fluid shortage has not been expected. Even though this may be true in most races, there have been competitions on warm days with considerable dehydration at the end of an 80 min race. Since also moderate dehydration has been shown to affect performance, it might be wise to consider serving fluid in shorter races on relatively warm days.

**Fluid replacement and sports drinks**

Concerning the issue of optimal post-exercise/race fluid replacement, this will only be briefly discussed here, thus the reader is recommended to consult some of the suggested readings for more detailed information. Nevertheless, it should be emphasized that good
routines on fluid replacement is perhaps the most important measure of recovery for an endurance athlete. The primary goal should be to prevent exercise-induced dehydration by starting each training session in liquid balance and by replacing fluid loss as soon as possible, i.e. while exercising. In doing this, the dehydration stress will be significantly reduced and the post-exercise re-hydration process will go faster.

When it comes to what types of fluid that is most effective, it is clearly demonstrated that the carbohydrate-electrolyte solutions are superior to plain water if the fluid loss has been of any significance (more than ca 1000ml). This is mainly because of their primacy in rapid absorption from the gut (correct osmolarity) and their ability to stay in the body (salt content). Since significant amounts of salt is lost in sweat during prolonged exercise, the salt/electrolyte content of the drink becomes gradually more important as the degree of dehydration increases. In fact, increasing the salt content of the drink consumed both during and after exercise will bring the athlete in fluid balance significantly faster that when drinking plain water only. Since the normal body fluid is “salt water” and not “fresh water”, it is obvious that both salt and fluid replacement is important. However, salt is not very palatable in drinks and this places a limitation to how much salts/electrolytes that can be replaced through fluid intake. That’s why a little extra table salt (sodium) on the food consumed after prolonged strenuous exercise may be recommended, unless hypertension or kidney problems are evident.

Picture: Ch3-sE-P2

Several commercial products of carbohydrate-electrolyte solutions in the form of various sports drinks are available. Some may have a little more or less of the major components, some may have vitamins and minerals or so called ergogenic components mixed in. Perhaps
the most striking difference is the taste and palatability of the drinks. However, when it comes to their ability in replenishing liquid, salt and energy, there is not much difference between the products. In fact, in a survey of the scientific testing that has been done and published, it is concluded that no commercially available sports drink is significantly better than any other on this three major effects. The most important factor may be the palatability and gastro-intestinal tolerability to the product, making it agreeable for plentiful consumption by the athlete.
Summary

1. When work intensity is maintained above 55-60 % of VO₂ max, carbohydrate --in the form of stored muscle glycogen and circulating glucose-- is the primary energy source for working muscle. The higher the work intensity the more carbohydrate --relative to fat-- is burned.

2. There is a limit to how much glycogen that can be stored in the body before exercise, thus, a shortage of carbohydrate fuels will develop after ca 90 min of high intensity exercise.

3. Even though different regimes of pre-race meal end exercise regimes have resulted in increased glycogen stores in muscles, there is very limited scientific data suggesting that this glycogen super-compensation it will result in enhanced race performance.

4. In preparations for a long distance race, the last meal should be completed at least three hours before start. Foods rich in carbohydrates --such as bread, oatmeal porridge or cereals for breakfast or rice, pasta, and potatoes for lunch-- is recommended.

5. Small portions of carbohydrates – such as a sandwich, banana, muffin or a cookie-- should be consumed every 15-30 min during the last 3h before the race, but during the last hour before start, carbohydrate-electrolyte drinks are preferable.

6. Research has demonstrated that intake of a carbohydrate-electrolyte solution – including glucose, sucrose, maltodextrins and sodium-- has a performance enhancing effect during prolonged (>60 min) strenuous exercise.

7. A carbohydrate intake of 1.0 -1.5 g/min (i.e. 800-1200 ml of a 6% carbohydrate solution) will provide the working muscle with enough energy to maintain a maximum oxidation rate of about 1.0 g/min.
8. A near isotonic solution of a carbohydrate-electrolyte solution will improve the gastrointestinal absorption and thus the availability of the carbohydrates during exercise.

9. Fluid intake is as important as energy intake for optimal endurance performance, and depending on the intensity of exercise and environmental conditions, fluid loss may exceed 1000 ml pr hour.

10. The primary goal of fluid intake should be to prevent exercise-induced dehydration by starting each training session in liquid balance and by replacing fluid loss as soon as possible, i.e. while exercising.

11. Since significant amounts of salt is lost in sweat during prolonged exercise, the salt/electrolyte content of the drink becomes gradually more important as the degree of dehydration increases.

12. The ability to replenishing liquid, salt and energy do not differ significantly between the commercially available sports drinks. The most important factor may be the palatability and gastro-intestinal tolerability of the different product in making it agreeable for plentiful consumption by the athlete.
Suggested readings


**Figure legends:** "Carbohydrate loading and fluid replacement"

Ch3-sE-Fig1
See scanned figure.

Ch3-sE-Fig2
See scanned figure.

Ch3-sE-P1
During preparation for a cross-country race, fluid intake should be large enough to produce a need for “unloading” surplus fluid once or twice during the last hour before start.

Ch3-sE-P2
Fluid replacement during long distance cross-country races is of paramount importance for optimal performance throughout the race. A minimum of 150-200ml of a carbohydrate-electrolyte solution should be consumed every 15-20 min. On warm days the volume of fluid should be increased, while on extra cold days the carbohydrate content may be increased, especially if racing more than 2.5h.

Ch3-sE-P3
When replenishing fluid loss from strenuous exercise with commercial sports drinks, the selection of type or brand of these drinks is not of vital importance. However, taste and gastro-intestinal tolerance may be key factors in using a drink that the athlete will consume sufficient amounts of for effective re-hydration.