Nutrition for Athletes

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Introduction

Proper nutrition is essential for athletic performance. It is the nutritional habits of the athlete that allow recovery, muscle building, injury repair, and general health. Without proper nutrition an elite athlete can be reduced to an average athlete. However, no nutritional program can raise an average athlete to the elite level; only a well planned and deliberate training program can provide that.

There are two main components of nutrition; the macronutrients and the micronutrients. There are four macronutrients; *carbohydrate*, *protein*, *lipids* and *water*. Together, these provide the basics elements for biological function. The micronutrients are the essential *vitamins* and *minerals*. Vitamins are biochemical molecules that the body is unable to make itself in sufficient quantities. Minerals are the inorganic elements required for cellular function.

A good diet is difficult to describe, however, there are a number of elements it should provide:

i. a variety of foods
ii. the recommendations of Canada's Food Guide
iii. foodstuffs as the prime source of nutrients
iv. weight loss of no more than 1 kg·week
v. provision for snacks as needed
vi. control of proportions

It should also involve the maintenance and promotion of good health, exercise as an integral part, and may require the consultation of a nutritionist or physician, if needed.

Macronutrients

Carbohydrate

Carbohydrates (CHO) are the main energy source for athletes. Sources of carbohydrate are classified as either simple and complex carbohydrates. Simple carbohydrates are either monosaccharides such as glucose, fructose and galactose or disaccharides such as sucrose (glucose + fructose) and lactose (glucose + galactose). Complex carbohydrates are large chains ofmonosaccharides such as glycogen and starch. For the athlete, the important biological sugars are glucose and glycogen. Glucose is a simple 6 carbon sugar and is found primarily outside of the cells. Glycogen is a branched polymer of glucose molecules and is one of the most efficient ways to contain glucose within cells.

At least 60% of the athlete's energy should come from carbohydrates. The appropriate number of grams of CHO can be calculated from 60% of the daily energy expenditure divided by 4 $Kcal \cdot g^{-1}$ carbohydrate. Most of this should be in the form of complex carbohydrates.

When in demand, carbohydrate is converted to adenosine triphosphate (ATP) a the carbohydrate supply exceeds the demand for energy, the excess is converted high energy, phosphate-containing molecule that can be used to power many biochemical reactions such as muscular contractions and neural impulses.

CARBOHYDRATE LOADING

Carbohydrate loading is a term often used in aerobic sports. The basic concept behind this dietary manipulation is to increase the carbohydrate intake in hope of inducing a supercompensatory response in muscle glycogen levels. In reality, no change is needed in diet to achieve this supercompensation. When an athlete begins to remove the training stress, her body will respond in such a way as to better accommodate that stress in the future. Part of this response is to increase glycogen levels. All the athlete needs to do is maintain a high carbohydrate intake (70-80%) while reducing training intensity and volume. When glycogen loaded, an athlete can expect to feel heavy and sluggish due to the elevated intra-muscular pressure caused by the glycogen and water stores. In some cases a few kilograms can be gained, and subsequently lost within a race of 2 hours.

Immediately following a workout, there is a period of time, known as the ***glycogen loading window***t. During this time, muscles are able to synthesize and store more glycogen than at other times. It is during this time that high carbohydrate foods, totaling 2g CHO / kg body weight) need consuming in small amounts at regular (15 minute) intervals over a 2 hour period. This will enhance the probability of adequate glycogen store replenishment before the next workout. Glycogen resynthesis in this time will be elevated by 300% over normal rates. Waiting more than 2 hours before ingesting food, decreases glycogen synthesis rates by 47%. Simple carbohydrates are best for this time period, as complex ones may be delayed in digestion too long to be effective. Liquid carbohydrate sources of up to 25% sugar may be used here (see section on “carbohydrate-protein drink”).

FIBER

Fiber is another form carbohydrate and is indigestible by humans. There are two forms of fiber, soluble and insoluble. ***Soluble*** fiber takes its name from being soluble in water and is found in gums and mucilages (oats, vegetables and fruits), hemicellulose (barley and legumes), pectin (seeds and rye) and psyllium (Metamusil). The RNI for soluble fiber is 12-30 $g \cdot day^{-1}$. However, due to its property of reducing low density lipopoprotein (bad cholesterol) concentrations in the blood, 25-30 $g \cdot day^{-1}$ is suggested.

The other form of fiber is ***insoluble*** in water and forms a gel like substance when wet. It is found in cellulose (bran) and hemicellulose (seeds, legumes, brown rice). Insoluble fiber is responsible for the prevention of constipation and hemorrhoids, prevention of bacterial infection of the appendix, and reduces the risk of certain forms of cancer (e.g. colon).

A high fiber diet, however, can lead to some nutritional problems. It may slow digestion, which for the athlete will mean impaired glucose absorption. High fiber diets can also reduce the absorption of certain vitamins and minerals (such as calcium). The water absorbed by or carried with the fiber can speed dehydration if additional water is not consumed to allow for this.

PROTEIN

Proteins are complex molecules consisting of amino acids and are essential for a number of cellular functions. Their main functions include: enzymes, acid-base buffers, antibodies, cellular membrane “pumps”, structural units, transportation, oxygen carrying molecules, and hormones. Proteins can also be used as energy sources and, during high intensity or long duration exercise, are capable of contributing 10% or more of the required energy.

The RNI for protein is 0.8 g·(kg body weight)$^{-1}$ for the average adult. This is about 10% of the total daily energy expenditure. The protein requirement for beginner athletes, endurance athletes and strength athletes are all greater than this. Beginner athletes need more protein (1.0-1.5 g·(kg body weight)$^{-1}$) to balance the elevated rates of muscle, enyzme and mitochondrial breakdown. Endurance athletes require more protein (1.0-1.2 g·(kg body weight)$^{-1}$) to balance muscle breakdown and amino acids used as fuel. Similarly, strength athletes have high protein requirements (1.2-2.0 g·(kg body weight)$^{-1}$) to increase muscle mass.

Excess protein in the diet, however, can lead to a number of problems. The most important of these would be the strain on the kidneys and liver caused by the additional processing requirements. Other problems are gastrointestinal disturbance, increased calcium excretion, increased vitamin B_6 requirement (for protein synthesis) and an increased risk of dehydration.

Endurance and high intensity exercise athletes will use protein as an energy source. The protein must first be deaminated ($-NH_2$ group removed) and converted to glycogen or to fats according to demand. The process of converting protein to glycogen is termed *gluconeogenesis*. The amount of protein used will depend on the athlete's training state, the intensity-duration-frequency of training, energy intake, quality of protein ingested and the carbohydrate intake. During a hard 60-90 minute effort, 30-35 g of protein can be consumed.

There are 20 amino acids needed in the human body, 9 of which are considered essential in children and stressed adults, such as athletes (see table). The essential amino acids cannot be synthesized by the body or cannot be synthesized in large enough quantities. Consequently, they must be ingested from the environment.

20 amino acids used in proteins.

Essential Amino Acids	Other Amino Acids
Histidine	Alanine
Isoleucine	Arginine
Leucine	Aspartic acid
Lysine	Cysteine
Methionine	Cystine
Phenylalanine	Glutamic acid
Threonine	Glutamine
Tryptophan	Glycine
Valine	Proline
	Serine
	Tyrosine

Protein quality is a measure of how much of the protein is absorbed by the body. This is a function of the source of the protein and the relative amino acid ratios. The quality of a protein source is measured against egg protein which has a biological value of 100, indicating all of the nitrogen ingested is retained. A second protein evaluation score is net protein utilization (NPU) where a value of 100 indicates all of the ingested protein is retained.

FAT

Nutritionally, lipids are energy storage molecules. They also serves as shock absorbers, insulation, vitamin storage media, hormone structure, and as biological membranes. As energy stores, lipids are very dense (9 Kcal/g) compared with glycogen. However, the density advantage that fat has over glycogen is mitigated in that access to fat stores is slow and can only occur at low intensities. As intensity increases, fat use is reduced in favour of the faster-access glycogen, glucose, and protein.

There are two main fat storage sites: extra-muscular and intra-muscular. The extra-muscular sites are generally larger. The number of adipocytes is determined early in life, after which only the size changes. These fat stores require longer to access due to the requirement for blood transportation. The intra-muscular lipid stores are droplets of fat within each muscle fiber. These are usually fixed in size, irrespective of exercise. Access to these fat stores is more immediate relative to the adipose tissues.

The athlete's diet should consist of 10-25% fat. Many athletes feel that fat should be eliminated from their diet altogether in order to minimize body fat. This can lead to health complications given that two fatty acids are essential. Linoleic and linolenic acid (also known as omega-3 or eicosapentanoic acid) can not be synthesized by the body in sufficient quantities for biological function. Approximately 3% of the total energy intake should be from linoleic acid and 1% from linolenic acid. Both of these fats are found in plants and fish and deficiencies are rare.

Dietary fats can be found in three forms; saturated, monounsaturated and polyunsaturated. Saturated fats are found mostly in animal sources and should be minimized (<10% total Kcal) in the diet. The majority of dietary fats should be from the poly- and monounsaturated varieties.

WATER

Water is often overlooked as a macronutrient even though it is needed in the largest quantities. Water provides the solution in which all biochemical processes occur. As an athlete, fluids are needed to:

i. maintain plasma volume which is directly associated with VO2 through cardiac output and blood pressure
ii. maintain blood osmolality needed for diffusion and osmosis
iii. provide effective thermoregulation
iv. be involved with carbohydrate storage
v. ensure electrolyte balance

During exercise, it is possible to loose in excess of 1,000 ml of water/hour. This is enough to severely compromise performance. To prevent fluid loss, it is best to replace fluid with small quantities (150-200 ml) on a regular basis (every 15 minutes) before thirst is apparent. If it is hot or humid, the athlete unacclimatized, the exercise session long (60+ minutes), or excessive sweat production is anticipated, then fluid intake should be increased. Caution should be used at altitude, as water loss tends to be accentuated.

One of the consequences of thermoregulation and sweating is dehydration. Water loss is affected by temperature, which modifies the rate of sweating. Additional factors that affect the rate of sweating are body surface area (larger area is better), gender (males are more efficient), and degree of hydration (hydration increases sweat rate).

Water loss estimates for a 70 kg male exercising at 80% peak VO_2.

temperature (C)	fluid loss
-05	0.6-1.4 l·hour^{-1}
10	1.2-1.5 l·hour^{-1}
20	1.6-2.5 l·hour^{-1}
30	2.0-2.8 l·hour^{-1}

Water loss resulting from exercise, has severe consequences for endurance athletes, as highlighted in the table below. It is important, therefore, to avoid dehydration at all costs.

Effects of water loss on performance.

BODY MASS LOST (%)	EFFECT
1	⇧ core temperature
2	⇩ plasma volume ⇩ muscle volume ⇩ stroke volume ⇧ heart rate ⇩ blood pressure
3	⇩ blood flow to skin
4	⇩ blood flow to muscles ⇧ [metabolite]muscle ⇧ probability of heat exhaustion
5	⇧ probability of heat stroke ⇩ [mineral]muscle ⇧ muscle spasms and cramps
6	⇧ urine specific gravity ⇧ urine acidity
7	⇧ urine protein ⇩ blood flow to kidneys ⇩ nutrient and O2 supply to kidneys ⇧ [toxins]blood

While dehydration can occur at a fairly rapid pace, rehydration is a long process if an athlete becomes dehydrated. Normally 48-52 hours are needed for complete rehydration. Cooler fluids are absorbed more easily than warmer fluids. Similarly, the presence of electrolytes and carbohydrates in the fluid will increase the rate of absorption. Electrolyte concentrations of 230 mg/l sodium and 195 mg/l potassium are the upper limits for elevated absorption. As for the presence of carbohydrate, gastric emptying is fastest with 2-5% glucose solutions, while intestinal absorption is unaffected by glucose concentrations of up to 10%. The rate of intestinal absorption, however, will vary between sports and individuals.

Micronutrients

Vitamins

Vitamins are organic substances required in trace amounts for proper health. They assist in or perform metabolic functions and can not be synthesized by the body. They are divided into two categories; fat soluble and water soluble, and include Recommended Nutritional Intake (RNI).

FAT SOLUBLE VITAMINS

VITAMIN A (retinol, retinal, retinoic acid)

SEX	RNI
Male	1000 RE
Female	800 RE

Vitamin A functions in maintaining the cornea, epithelial cells and mucous membranes. It is also involved in skin, bone and tooth growth, reproduction, hormone synthesis and regulation, various aspects of immunity, and cancer protection. Vitamin A is also considered to be an antioxidant along with vitamins C and E.

This vitamin is found as β-carotene in plant sources and retinol in animal sources. Green leafy or yellow-orange fruits and vegetables are good sources of vitamin A, while fortified dairy products and liver are good animal sources. An RE is a retinol equivalent and means 3.3 IU of retinol or 10 IU of β-carotene. Taking 5-10 times the RNI may cause problems such as fatigue, head aches and liver damage.

VITAMIN D (calciferol, cholecalciferol, dihydroxy-vitamin D)

AGE	RNI
19-49	2.5 μg
50+	5.0 μg

Vitamin D regulates calcium and phosphorus concentration in the blood by acting on bone mineralization rates and intestinal absorption, resorption and excretion. Initially this vitamin is inactive and requires activation by sunlight to convert to its biologically active form.

Good sources of vitamin D are fortified dairy products, cod liver oil, and sunlight. Exceeding the RNI by 8-10 times is considered dangerous and can lead to calcium deposits in soft tissues.

VITAMIN E (alpha-tocopherol, tocopherol)

RNI

AGE	MALE	FEMALE
19-24	10 mg	7 mg
25-49	9 mg	6 mg
50+	7 mg	6 mg

Vitamin E is an antioxidant and helps to stabilize cellular membranes, and protects polyunsaturated fatty acids (PUFA) and vitamin A against free radical damage. The role of vitamin E in cancer prevention remains inconclusive.

Sources of vitamin A are whole grains and vegetable oils.

VITAMIN K (phylloquinone, naphtoquinone)

SEX	**RNI** (increasing by age)
Male	45-80 mg per day
Female [1]	45-65 mg per day-

Vitamin K is important in the synthesis of blood clotting proteins and blood calcium regulating protein.

Sources of phylloquinone are obtained from food products and from intestinal bacteria. The intestinal bacteria provide about half of the RNI and the rest can be obtained from dark green leafy vegetables and liver.

WATER SOLUBLE VITAMINS

VITAMIN B1 (thiamine)

RNI 0.4 mg per 1000 Kcal
0.8 mg minimum

Thiamine is part of the coenzymes used in energy metabolism. It also helps in the maintenance of appetite and nervous system function.

Sources of thiamine include pork, legumes, whole grains, enriched breads, and cereals. Excess is excreted due to its water solubility.

VITAMIN B2 (riboflavin)

RNI 0.5 mg per 1000 Kcal, 1.0 mg minimum

Riboflavin is an essential part of energy metabolism in the form of the “energy” transfer molecule FAD, as well as other coenzymes. It has additional roles in supporting vision and skin maintenance.

Vitamin B2 is found in dairy products, organ meats, whole grains, enriched breads and cereals. Excess is excreted due to its water solubility.

VITAMIN B3 (niacin, nicotinic acid, nicotinamide)

RNI 7.2 NE per 1000 Kcal
14.4 NE minimum

Vitamin B3 is used in energy metabolism for the release of carbohydrate, fat and protein. It is primarily used in carbohydrate metabolism. It is also used in the maintenance of the skin, and the nervous and digestive systems.

Sources of niacin are meat, poultry, beans, whole grains, enriched breads and cereal. Any excess niacin in the system is excreted. However, during the time the excess is being removed, a “niacin rush” can result in vasodilation, flushed skin, and a superficial tingling sensation. It will also decrease the rate of fat breakdown if >2 $g \cdot day^{-1}$ are ingested. In the case of large doses on a regular basis, liver damage may result.

VITAMIN B6 (pyridoxine, pyridoxal, pyridoxamine)

RNI 0.15 mg per gram protein

Pyridoxine has functions in amino acid metabolism, the conversion of tryptophan to niacin, and hemoglobin formation. It also serves a role in glycogenolysis, the release of glycogen in muscles or the liver.

Sources of B_6 are organ and muscle meats, whole grains and fruits such as bananas. Excesses can lead to sleepiness (>150 mg), dependencies (>200 mg), and nausea, diarrhea and nervous system disorders (>1000 mg).

FOLATE (folic acid, folacin, pteroylglutamic acid)

SEX	RNI
Male	220 μg per day
Female 1	175 μg per day

Folate is involved in cellular division and the formation of red and white blood cells.

This vitamin is present in green leafy vegetables, liver, fish, poultry, legumes and fruit. Folate loses its strength over time with exposure to sunlight and oxygen. In excess it can interfere with certain drugs (e.g. anticonvulsants) and mask B_{12} deficiencies.

VITAMIN B12 (cyanocobalamin)

RNI 2 μg

Vitamin B12 functions in the maintenance of nerve cell insulation (myelin) and red blood cell production. There are inconclusive reports of an ergogenic effect for cyanocobalamin when injected in amounts of 1000 μg. It supposedly elevates aerobic capacity, strength, and power.

This vitamin is unique in that it requires Castle's Intrinsic Factor to be absorbed. Sources of B_{12} are limited to animal products such as dairy, seafood, and other meats. There are no known problems caused by excess.

PANTOTHENIC ACID

RNI (none established)

Pantothenic acid is an essential part of energy release from nutrients. It is widespread in many foods. Deficiencies are associated with disease usually.

BIOTIN

RNI (not yet established)

Biotin is a coenzyme factor used in energy metabolism, fat synthesis, amino acid metabolism and glycogen synthesis. There is no shortage of biotin in common foods, thus, deficiencies are usually precipitated by disease.

VITAMIN C (ascorbic acid)

SEX	RNI
Male	40 mg per day
Female 1	30 mg day

Vitamin C is important in the formation of collagen required for healthy bones, gums and teeth. Collagen is also important in the healing of wounds. Vitamin C is also important in increasing iron absorption and as an antioxidant.

Key sources of vitamin C are citrus fruits, berries and some vegetables. High doses of vitamin C are very popular although this has no scientific support as being beneficial. Excess can lead to kidney stones, damage to the enamel of teeth (with chewable tablets), destruction of vitamin B12, impaired infection resistance, and diarrhea. If higher amounts of vitamin C are thought necessary, it is best to supplement with additional fruits and vegetables.

Minerals

Mineral intake and mineral absorption are two different processes. There is a process known as the gatekeeper mechanism that acts to minimize the possibilities of deficiency and toxic levels of minerals in the body. This mechanism increases the sensitivity and absorption of a mineral when stores are depleted and will decrease sensitivity and absorption when stores are saturated.

The most important major and trace minerals, their importance to the body and the Recommended Nutritional Intakes (RNI) are noted in the following pages.

MAJOR MINERALS

These minerals are required in daily amounts greater than 100 mg.

Calcium (Ca2+)

Sex	**RNI**
Male	800 mg per day
Female [1]	700 mg day
	1000mg per day (ammenorrheic)
	>700mg per day (post menopausal)

Calcium is the main mineral component of bone and teeth (90%). The bones are the primary storage place for calcium and it is constantly being deposited and reabsorbed. This process is known as ***remodeling*** and can occur as a response to stress on the bones or hormonal action from the blood.Calcium is essential for the contraction of all muscles and the transmission of nerve impulses. It also regulates ion transport across cell membranes. In the circulatory system it helps maintain blood pressure and clotting. Calcium also makes up the inter-cellular matrix that binds cells together.

Calcium deficiencies are quite serious as they can lead to calcium imbalances if they are chronic (years). Calcium is found in dairy products such as cheese and milk and in sardines or salmon where the bones are processed with the meat. Primary vegetable sources of Ca are broccoli and legumes. There are a number of factors that will affect calcium absorption rates. Age and gender are two such factors. Infants and children will absorb ~60% of the dietary Ca, pregnant women ~50% and other adults ~30%. Another factor affecting Ca absorption is the acidity of the stomach; low acidity will reduce absorption (such as with antacids, Tums or Rolaids). Lactose (milk sugar) promotes Ca absorption as does Vitamin D (calcitriole) and a 1:1 Ca:-P ratio in the diet.

Calcium loss from the body is increased by a number of factors;

i. high protein diet

ii. diseases of the intestines (absorption decreased), liver (low Vitamin D), pancreas (low acidity) and parathyroid gland (low calcitonin- Ca deposition hormone)
iii. diarrhea (reduces time available for absorption)
iv. medication such as corticosteroids, antacids and tetracycline (by way of need to avoid dairy products)
v. high caffeine intake
vi. high dietary fiber intake will bind Ca and cause it to be excreted
vii. smoking

OSTEOPOROSIS

Osteoporosis, or the loss of bone density, is the primary manifestation of calcium deficiency. This disease is age and gender dependent with older females being at higher risk. There are two forms of osteoporosis, type I or post menopausal osteoporosis, and type II or senile osteoporosis. Females are 6 times more prone to type I osteoporosis which affects the spongy (trabecular) bone, resulting in the disintegration of the interior of the vertebrae in particular. Type II osteoporosis affects both trabecular and dense (cortical) bones, weakening such areas as the hips (femur). Females have twice the risk of men for developing this disease. With proper diet and exercise peak bone density will occur at age 30 and bone loss can be noticeable by age 55. Increasing Ca intake through supplements and participation in weight-bearing exercise is widely advocated for females and older adults. However, calcium supplementation carries a few risks such as kidney stones, decreased iron absorption, muscular weakness, cardiac arrhythmia, decreased magnesium absorption, and constipation. If supplementation is taken, the best form of Ca is calcium carbonate which contains ~60% elemental Ca. This should be taken between meals when acidity is highest, unless absorption problems are present, in which case during meals is best.

PHOSPHORUS (P-)

SEX	RNI
Male	1000 mg per day
Female 1	850 mg day-

The second largest mineral component of bone is phosphorus. It is essential to the buffering capacity of cellular fluids in its salt form. Another function of phosphorus is in high energy molecules. These molecules, such as ATP, ADP, AMP, CP and Pi, store chemical energy in an easily accessible form for biochemical reactions. Phosphorus is also an integral part of all cellular membranes as phospholipids. There are no known deficiencies of phosphorus as it is in abundant supply in most animal and plant produce. Ingesting a 1:1 ratio of P and Ca promotes absorption of both of these minerals.

SODIUM (Na+)

RNI 9 mg per kg, 500 mg per day maximum

This is the most well known mineral, especially in its most common form, table salt (NaCl). Sodium is essential for all cellular function and consequently 30-40% of it is stored on the surface of bones for rapid access. There is no shortage of Na in foods and only rarely will a sodium imbalance occur. Excess Na can lead to hypertension if the amount of sodium exceeds the clearance capacity of the kidneys.

The amount of Na lost through sweat is approximately 1 g. The excessive loss of Na is termed hyponatremia and is more common in ultra endurance athletes in hot conditions. With training and acclimatization, less sodium is lost by way of sweating.

POTASSIUM (K+)

RNI 30 mg per kg

Potassium is essential for cellular function (especially muscle and nerve cells) and maintaining fluid and electrolyte balance. Potassium is adversely affected by dehydration, although it takes a number of days in a dehydrated state to deplete K stores. Potassium is abundant in most whole foods and deficiencies are rare.

MAGNESIUM (Mg)

SEX	**RNI**
Male	250 mg per day
Female 1	200 mg day-

Magnesium is essential to the function of many enzymes and energy using processes. Mg is also needed for muscle relaxation and nerve transmission. An additional function of Mg is in the prevention of tooth decay.

Mg is stored in the bones and reabsorbed into the blood as needed. The RNI for Mg is rarely met and athletes will loose more through sweating. Attention should be taken to include Mg rich foods in the athlete's diet. Examples of these are green leafy vegetables, whole grains, legumes, nuts, and seafood.

TRACE MINERALS

Trace minerals are required in quantities of only a few milligrams per day to maintain a healthy body.

IRON

SEX	**RNI**
Male	9 mg per day
Female 1	13 mg day-

This mineral is essential for O_2 transportation and energy metabolism in the mitochondria as cofactors and coenzymes. In the body, 69-75% of iron is stored as hemoglobin (Hb) and myoglobin (Mb), 15-30% as metalloprotein complexes used for iron transport and storage, such as ferritin (10%), hemociderine (9%) and transferrin (0.2%), and less than 1% is stored as enzymes.

Iron losses are cumulative from a number of small sources. The largest of these is the diversion of blood flow from the digestive system, reducing iron absorption time. Another is the lysis of red blood cells and the release of hemoglobin into the blood. This can be a large loss for athletes who do a lot of running. Mechanical stress to cells will also cause a loss of iron, as will hypoxia. Iron can be lost directly through the menstrual cycle, and through perspiration, urine, and feces, especially after high intensity workouts. Serum ferritin reflects the total iron stores and should be evaluated during off season, during high load, and post competitive season in order to identify those athletes at risk of developing anemia (low iron levels).

Iron is best obtained from meat as heme iron, which has an absorption rate of 20-30%. Vegetable and supplement forms of iron (non-heme iron) are poorly absorbed (2%). Vitamin C and phosphorus promotes iron absorption while phytates in caffeine sources, Ca, and alkaloids reduce iron absorption.

If iron supplementation is used, it should be noted that excess iron becomes insoluble in the form of hemociderine and cannot be released at a later date. If quantities are sufficiently large, the insoluble iron will accumulate to toxic levels for the cells. Additionally, excess Fe can lead to zinc deficiency which in turn can lead to a copper deficiency, which can increase the risk of iron deficiency.

Strongly associated with iron use is the hormone erythropoietin (EPO) that regulates red blood cell synthesis. EPO is stimulated by hypoxia as sensed in the adrenal cortex of the kidneys. This can be caused by decreased blood Hb, incomplete oxygenation of Hb (altitude, lung disease, heart disease) or an impaired O_2 release from Hb at normal conditions.

ZINC (Zn^{2+})

SEX	**RNI**
Male	12 mg per day
Female 1	9 mg day-

Zinc is associated with protein synthesis, bone structure, the management of CO_2, vision, and reproduction. In vegetarian diets, Zn deficiencies are common, especially if unleavened (without yeast) bread is used exclusively. Zinc stores are reduced by high Fe levels and similarly, excess Zn can lead to copper deficiency. Zinc is found primarily in meat, whole grains, and milk.

COPPER (Cu2+)

RNI 2 mg per day

Copper is an essential cofactor in the protein complex ceruloplasmin which is synthesized in the liver. This protein is part of the inflammatory response to injury. It also serves as a superoxide scavenger that prevents oxidation damage during long or intense exercise. Another ceruloplasmin function is the reduction of Fe^{3+} to Fe^{2+} for transferrin pickup, thereby enhancing iron absorption. Copper is also incorporated into the insulating myelin sheath around nerves, into collagen fibers, and is involved in the fat metabolism process.

A deficiency in copper can lead to a deficiency in iron, thereby completing a complex negative feedback loop starting with excess iron. Food sources of copper are shellfish, whole grains, organ meats, legumes, fruit and vegetables. Copper is often lost in processing of high sugar preservations. Supplementation for copper is best done with a multi-vitamins, if food sources are not available. However, 10 mg copper can cause nausea and 3.5 g is considered toxic.

CHROMIUM (Cr2-)

RNI not yet established

Chromium is an active ingredient in glucose tolerance factor, a compound that increases the efficiency of insulin. Cr is lost through sweat and urine especially in athletes with high volume or intensity training programs, reduced energy balance, or high intakes of refined foods. Natural sources of Cr are mushrooms, chicken, brewer's yeast (wine and beer), peppers, shellfish (oysters), and apples. High chromium intake may have negative effects on iron absorption and induce some minor hormonal changes.

Nutrition Basics

Canada's Food Guide

Canada's Food Guide provides an excellent overview of standard nutritional basics. It identifies the four food groups and sources for obtaining various nutrients. For details, consult the guide provided by Health and Welfare Canada. Keep in mind that these recommendations are for the average person, not high performance athletes.

Because of the critical role of nutrition for elite athletes, ***vegetarianism*** should be avoided. Unless the athlete is extremely well informed about maintaining a balanced diet within the vegetarian lifestyle, coaches should council against it. A balanced diet that includes meat is preferable for athletes in training.

Athlete Considerations

Endurance athletes need to increase their caloric input to at least balance the caloric output. If they do not, they will loose weight not only in the form of fat but also as muscle (protein) mass. During exercise, undernourished athletes will consume some lipid stores but they will also catabolism muscle mass for energy. If energy is not available for exercise and the natural repair process, the athlete's performance will suffer in the long run. Endurance and strength athletes generally require larger percentages of protein than sedentary individuals. The RDI of protein for athletes should be raised to 1.8-2.0 g/kg.

HIGH CARBOHYDRATE -LOW FAT DIET

Endurance athletes must consume large amounts of carbohydrates in order to sustain their training regimens. Achieving a high caloric intake of carbohydrates without increasing fat intake is sometimes difficult. Therefore, a few basic suggestions have been offered. For breakfast, lunch, and supper menus:

i. eat meals consisting largely of CHO foods such as breads, cereals, potatoes rice, pasta, vegetables, and fruit
ii. if it is difficult to satisfy the appetite, increase the fibre content by eating more whole grain foods
iii. add quantities of low fat protein foods such as fish, chicken, lean red meat, eggs, cottage cheese, legumes, and skim milk
iv. minimize the use of butter, margarine, and mayonnaise on bread
v. minimized the use of fat in cooking by baking, steaming, boiling, grilling, using the microwave, or stir-frying
vi. use only lean cuts of beef, lamb, or pork, and remove skin from chicken
vii. eat fish fresh or canned in water
viii. use low fat milk products such as skim milk, low fat cottage cheese, no-fat sour cream,
ix. yogurt made with skim milk, or buttermilk (hard cheeses have higher fat content)
x. avoid cream, sour cream, cream cheese, high fat salad dressings, ice cream, mayonnaise, cakes, pies, pastries, chocolate, potato chips, and fast foods

PRE-COMPETITION NUTRITIONAL SCHEDULE

The diet an athlete follows before a competition is important for peak performance given that all other aspects of preparation have been completed as required. The following schedule outlines a framework from which an individual schedule can be developed for each athlete based on his or her needs:

TIME	SCHEDULE
6-4 days	65% CHO diet plenty of fluids
3-1 days	70% CHO diet fluids in excess avoid alcohol avoid caffeine
3-5 hours	>500 Kcal meal (70% CHO) fluids in excess avoid alcohol avoid caffeine
1-2 hours	500 ml·hour^{-1} water, avoid added CHO
15 minutes	250-500 ml water
event	125 ml·15 minutes^{-1} fluid >2 hours use CHO polymer drink
post	500+ ml fluid
0-2 hours	fluid in excess 0.5 g CHO·kg^{-1}·15 minutes^{-1}

Eating Disorders

Athletes, both male and female, who become overly concerned about body weight, percent body fat, or body image should be considered at risk for eating disorders. Eating disorders include anorexia nervosa (excessive negative caloric balance) and bulimia nervosa (bingeing and purging). All eating disorders should be considered serious and a physician consulted as soon as possible.

ANOREXIA NERVOSA

Anorexia nervosa brings to mind the image of the emaciated female gymnast or dancer who eats next to nothing. This disease is characterized by a deliberate self-starvation with profound psychiatric and physical components. A more recent form of this is the classification of males as anorexic. While females restrict caloric intake to maintain the negative caloric balance, males do the opposite. They will eat apparently normally but exercise to an excess to burn more calories to achieve the negative balance. This is especially common in sports where the shape of the athlete’s body is quite visible (swimming, triathlon, running, and possibly skiing).

BULIMIA

Bulimia is an eating disorder characterized by periodic binge eating. Bulimic individuals realize their behavior is abnormal but are unable to control it. Bulimia nervosa follows the bulimia pattern of bingeing and adds on a purging phase. During the purging phase, the bulimic will use laxatives, diuretics and self-induced vomiting in an attempt to rid themselves of the food.

Travel Considerations

Nutrition On the Road

There are a number of common sense rules that need following while on the road.

WATER

The first guideline regards the consumption of water. It is easy to overlook fluid intake during travel and in an unfamiliar environment. It is recommended that all athletes have a 1-2 l bottle that they carry with them everywhere. If the water at the destination is of uncertain quality, it may be best to purchase bottled water for drinking. This is advisable for any destination outside of Canada and the USA. Small differences in the local water bacteria can severely upset gastro-intestinal processes of some athletes. If bottled water is not a viable option then alternatives are to either boil the water (10 minutes at a boil), disinfect it, or filter it. Washing and brushing teeth should be safe and of little to no concern, just do not drink it. Remember that freezing water will not purify it, consequently ice cubes are just as bad as tap water.

RESTAURANTS

As for food, most of the recommendations have to do with avoiding food born sicknesses caused by improper preparation. The improper preparation of food is one of the primary concerns of nutritionists when it comes to health risks not related to a balanced diet. Keep the following guidelines in mind when selecting where to eat, especially considering that while some food may look wonderful and reflect a taste of the country, it is not worth the risk. What native inhabitants may have immunity to, the athletes may not.

i. at buffet style meals eat only when the food has just been served or uncovered
ii. avoid pork and pork products
iii. avoid street vendors
iv. go to restaurants recommended for travelers, not those recommended by the locals which may be better, but unsuitable for the athletes
v. avoid any food left uncovered or in the open
vi. wipe the cutlery clean before eating

FRUIT AND VEGETABLES

It is also a good idea to wash and peal fruits and vegetables, if possible, before eating them. In this way, any parasites or chemical products (pesticides or fertilizers) banned in North America can be avoided. This is a small price to pay for the lost nutritional value of eating the peal.

FOOD PREPARATION

When preparing your own food on the road, try to choose pre-packaged foods that you recognize. Road trips are not the place to experiment with culinary skills.

JET LAG

Jet lag is a condition that arises from travel across time zones and is attributed to a disrupted circadian rhythm and associated dehydration. The effects of jet lag are often described as: difficulty sleeping, general fatigue, general discomfort in muscles and joints, irritability, and reduced sensory-motor performance.

The effects of jet lag and travel can be minimized by a number of precautions;

i. plan arrival times at the destination for the morning (get active right away)
ii. plan the last hard workout not less than 6 hours before the flight
iii. try to sleep on the trip
iv. move around and stretch when not sleeping
v. utilize good nutritional behavior

Nutritional Concerns

The two main nutritional concerns during travel are dehydration and food consumption. Habits on arrival at the destination can also affect recovery from travel.

DEHYDRATION

Dehydration is a big problem during travel, especially when flying. To avoid dehydration, a conscious effort is needed to consume 250 ml/hour of cool water or similar fluids. This practice should be followed for the entire travel day, not just in the travel portion. During this time alcohol and caffeine should be avoided out of concern for their diuretic effects.

FOOD CONSUMPTION

The foods consumed on the travel day are equally important. Athletes should not change their diet from the regular training regime. This may mean bringing food on the trip. Foods with high carbohydrate content are best. They will help prevent dehydration by retaining water with the carbohydrate. Most airlines have special meal plans from which a suitable low-fat/vegetarian/high carbohydrate meal can be pre-ordered (48 hours in advance is best for ordering meals). Whenever possible, protein dense foods should be avoided. Each athlete should also be responsible for preparing a personal supply of snacks for the trip to avoid long periods without food. High fiber foods will also help minimize the effects of any dehydration related constipation problems.

DESTINATION HABITS

On arrival at the destination, immediately adapting to the local time pattern will accelerate the transition to the new schedule. Spending time keeping active, especially in sunlight, as well as eating meals and sleeping at the appropriate times, will speed recovery and adaptations. To fully adapt, it is generally considered that an athlete needs one day per hour of time zone change. The time spent adjusting to a new time zone, however, can be reduced by beginning to adjust sleep and eating schedules before departure.

ERGOGENIC AIDS

Nutritional misinformation is everywhere in sports nutrition. Nowhere is this more apparent than in advertising. Warning signs that you are entering an area where marketing, not science, is selling a product are relatively easy to identify:

i. dissected and limited quotes
ii. inaccurate of incomplete referencing
iii. testimonials of famous athletes or coaches
iv. the use of the term "patented"
v. independent studies
vi. unpublished results
vii. unobtainable results or data
viii. outdated or old research that has been since refuted mail order testing or analysis quoting values and numbers that may well be within normal physiological ranges

The general rule, to follow in deciding the value of a product is that if it sounds too good to be true, then it is probably is! You are the one eating/drinking the product and you should know what is in it.

Although a balanced diet should supply sufficient quantities of all nutrients, there are a few proven nutritional ergogenic aids that are worth mentioning. These include caffeine, glucose drinks and glucose-protein drinks. Others are more controversial such as L-carnitine, alkaline salt loading, phosphate loading, inosine, and glycerol. There are also products that require a degree of caution, such as new diets, amino acid supplements and vitamin supplements.

Caffeine

Caffeine is a proven ergogenic aid and as such it is a banned drug according to the IOC Medical Commission. In large doses, caffeine can increase performance in endurance athletes by up to 10%. This advantage is on par with the performance enhancing effects of blood doping.

Caffeine enhances performance by increasing the amount of calcium released in muscle cells, thereby reducing the effects of fatigue. It also increases the rate of fat metabolism and inhibits cyclic AMP (cAMP) degredation resulting in elevated epinepherine levels.

The effects of caffeine are most apparent in long events where muscle glycogen stores are at risk of becoming depleted (2 hours or longer). To be effective the caffeine dosage must be taken approximately 3 hours prior to the desired time of effect. An individual's response to caffeine is variable and depends on body composition and sensitivity. Habitual caffeine users will have a blunted response as compared to caffeine-naïve individuals.

There are number of negative side effects to caffeine usage. The most serious being disqualification and suspension if the allowed dosage is exceeded. This amount is 12μg·ml and corresponds roughly to 17 cans of Coke, 17 cups of tea, 9 cups of coffee or 4 Vivarin. Other negative effects include increased anxiety, nervousness, headaches and possibly diarrhea.

Carbohydrate Energy Drinks

Energy drinks are invaluable to both training and longer races (45 minutes and longer). They provide an immediate energy supply to replenish blood glucose levels and prevent loss of glycogen stores. These drinks are composed of simple and complex carbohydrates. Fluids with high simple carbohydrates will provide a short term energy supply while complex carbohydrates will provide a much more even, long term energy supply. Ideally a combination of the two will provide the best results.

Contrary to popular belief, ingesting high concentrations of simple carbohydrates immediately before competition is not detrimental. However, simple sugars ***more than*** 5 minutes before competition will have negative performance consequences. Additionally, some athletes have reported that high concentrations of fructose can cause gastro-intestinal distress and discomfort.

Effect of carbohydrate ingestion relative to the time-to-performance.

CARBOHYDRATE	TIME	BLOOD GLUCOSE	MUSCLE GLYCOGEN	PERFORMANCE
glucose	>30	□	↔	□
	0-5	□ or ↔	↔	□
fructose	>30	↔	↔	□ or ↔
	0-5	□ or ↔	↔	□
glucose	>180	□ or ↔	↔	□

The concentration of the energy replacement drink should be less than 5% for glucose solutions when optimal gastric emptying is being considered (hydration considerations), and less than 10% when intestinal absorption rates are important (energy considerations). The carbohydrate in an energy drink should provide 25-30 g·hour^{-1} to improve performance and be consumed at a rate of 250 ml·¼ hour^{-1}. The type of carbohydrate used will affect the rate of absorption. Simple molecules will have high osmolalities while complex molecules will have low osmolalities for a given weight. However, the rate of intestinal absorption will vary between sports and individuals.

A final couple of considerations with regard to energy drinks, in general, involve taste and familiarity. The taste of the drink is important so that the athlete will drink on a regular basis and not "forget to drink". The familiarity of the drink becomes important in competition. If a product has not been used in training then it should not be used in competition.

Carbohydrate-Protein Drinks

New on the sports nutrition scene are carbohydrate-protein drinks. In addition to the carbohydrate component, these drinks contain high biological activity proteins (from eggs or milk), branch-chain amino acids or both. These drinks are for long workouts (2+ hours), long races (2+ hours), and recovery. The protein component in these drinks limits the catabolism of protein (especially muscle mass) during exercise and enhances recovery rate.

Branch-chain amino acids, through a complex series of steps, reduce the production of the neurotransmitters responsible for fatigue, thereby prolonging the possible time at maximal effort. With the carbohydrate-protein fluid replacement, top US swimmers were able to recover adequately from two to three intense workouts per day, within 24 hours, unlike with carbohydrate alone, protein alone, or water drinks which took in excess of 48 hours. These swimmers demonstrated little residual muscle damage, signs of muscle mass catabolism, or loss of lean body mass.

L-Carnitine

This biochemical molecule is present in muscle cells in small quantities and is used in a key process in fat metabolism. The theories behind its use as an ergogenic aid arise from beliefs that this is the rate limiting process in β-oxidation and, as a result, will spare muscle glycogen. To date, research has been inconclusive with many inconsistencies in methodology and results. The research originated in Italy in the early 1980's and has only recently (1990's) begun to attract more academic interest.

There are two forms of carnitine, the L and D isomers. Isomers are identical molecules except for the fact that they are mirror images of each other. The L isomer of carnitine is the biologically useful one for humans. The D isomer will inactivate the L form. Supplements should contain only pure L-carnitine for full utility. Less expensive mixtures of L and D-carnitine are often sold and will be less active. It should be noted that L-carnitine is available from natural food sources such as lamb and dairy products.

Alkaline Salt Loading

The belief that ingestion of alkaline salts will increase the pH buffering capacity of the blood is the basis for the proposed ergogenic effects. The benefits of this ergogenic aid are limited to very high intensity, short duration activities (less than 5-7 minutes). As with L-carnitine the results are inconclusive.

The dosage of alkaline salts, such as bicarbonate or baking soda, is in the range of 300 $mg \cdot kg^{-1}$. There are a number of unpleasant side effects associated with alkaline salt ingestion in the required quantities. These include "explosive" diarrhea within 60 minutes of ingestion, muscle spasms, irritability, delirium and elevated urine pH.

Phosphate Loading

The essential major mineral phosphorus, is part of the molecule phosphate (PO_4^{2-}). The ergogenic effect suggested here is derived from increasing the ATP-CP stores, decreasing the blood [La^-], and an increased activation of energy production B complex vitamins.

The required dosage has been suggested at 1 g of sodium phosphate taken 4 times daily for three to four days prior to the competition, with the last dose 3 hours before the event. There are no known side effects to date.

Inosine

Inosine is a nucleic acid that occurs naturally in the body. It is a precursor and byproduct of adenosine. Adenosine is a component of ATP, DNA, RNA, and protein synthesis. The theories supporting the ergogenic qualities of inosine promote it as capable of increasing O_2 utilization and enhancing muscle mass growth. However, there is little supportive evidence and that which is available, is questionable. Side effects of inosine supplementation are an increased risk of gout and an excess production of uric acid. Uric acid increases are associated with free radical formation and cell membrane damage.

Glycerol

This simple molecule is very new on the ergogenic aid scene. It increases the water compartment of the blood (plasma) and thereby elevates the O_2 carrying capacity of the blood by a mechanism known as hypervolemia. This mechanism will delay fatigue at high intensities and over long durations. Additionally, it will delay dehydration through the increased hydration that accompanies the increased plasma volume.

Amino Acid Supplements

Amino acid supplements and protein powders are another popular dietary item. This apparently harmless habit appears to be an ideal way to increase protein intake, gain muscle mass, or prevent muscle breakdown. The truth of the mater is that protein intake is a complex process requiring a ***BALANCED*** protein or amino acid source. This is achieved by way of protein rich foods. Very often supplements may have deficiency in one or more amino acids, especially isoleucine, phenylalanine or threonine.

Amino acids are taken into the blood by transport molecules that recognize a number of similar amino acids. If one of these is present in much higher concentrations than the others, as in supplements, it will compete with the others for receptor sites, resulting in the others being absorbed in lower concentrations. The safest way to supplement protein is through increased overall energy intake or through skim milk powder (caseine).

Vitamin Supplements

Vitamin supplementation is a very common practice among athletes. However, there is little conclusive evidence that vitamin supplementation is necessary. With training athletes consuming a balanced diet, there is little chance for a vitamin deficiency. If possible, dietary changes should be made before supplementation is considered. Unless prescribed by a dietitian or physician, the most an athlete should take is a multi-vitamine.

"Special" Diets for Athlete

New diets are always being introduced as the latest product designed to raise performance. An example of a diet with no scientific background among endurance athletes is the 40:30:30 diet, where 40% of the energy comes from carbohydrate and 30% from each of protein and fat. While most diets are relatively harmless, this diet may cause more damage to athletes than at first apparent. The primary problem with this diet for athletes is that muscle glycogen will be low, if not depleted, on a chronic basis. A secondary problem is the stress on the kidneys caused by the high protein intake. This is due to the elevated rate of protein catabolism and subsequent excretion of these metabolic by-products (nitrogen products). The theory that created this diet concerns the dynamics between the hormones insulin and glucagon. The logic becomes flawed when the fact that most endurance athletes rely on glucose and glycogen for energy. These will not be provided by this diet and consequently the benefits from the athlete's training will decrease and performance will suffer.