CHAPTER 6 - Diet and Nutrition

2.1.1 Nutrition and weight management

A **balanced diet** is (figures 6.1 and 6.2) the combination and proportions of carbohydrates (CHO), fats, proteins, roughage, water and essential minerals and vitamins which best provide for a sportsperson's nutritional requirements. Table 6.1 gives the details of each food type and its contribution to life.

figure 6.1 – a balanced diet?

figure 6.2 – balanced diet

Table 6.1 – **summary of dietary content**

type of food / sources	function as a food fuel - how it is used	energy content (kJ g^{-1})	percentage in a balanced diet
carbohydrate (CHO) sugars, rice, potatoes, pasta	**main energy supply**, absorbed as glucose in small intestine, transported around body as blood glucose. available for immediate energy. excess stored as muscle and liver glycogen and as fat.	17	60 %
fats butter, oil, pastry, fried food	**secondary energy supply**, absorbed as fatty acids and glycerol in the small intestine, stored as triglycerides in adipose tissue. **triglycerides** conveyed to the liver via the circulatory system. in the liver they are converted to **glucose**, available as delayed (20 minutes delay) energy source for long duration low intensity **aerobic** exercise.	39	20-25 %
proteins meat, eggs, milk, cheese, nuts	absorbed as **amino acids** in the small intestine, used for growth and repair by all tissues. used as an energy source when body is depleted of CHO and fat. excess protein not needed for tissue repair is broken down and used as an energy supply.		10-15 %
vitamins	organic substances needed for crucial functions in almost all bodily functions. regulate metabolism and facilitate energy release. have important functions in bone formation and tissue synthesis.		small amounts essential
minerals	**calcium** provides structure in bones and teeth. **iron** is needed for red blood cell production. **other minerals** assist in synthesising glycogen, fat and protein.		small amounts essential
dietary fibre wholegrain cereals, vegetables	non-starch, structural polysaccharide including cellulose, only available from plant sources. gives **bulk** to food residues in the intestines. aids **gastrointestinal** functioning.		large amounts necessary 20 to 40 grams per day
water	constitutes 72% of **muscle weight** and around 50% of adipose tissue, provides the body's transport and reactive medium. **transports** nutrients and leaves the body in urine and faeces. **lubricates** joints, keeping bony surfaces from grinding against each other. provides **structure** and form to the body, some sports drinks are designed to meet both energy and fluid needs of athletes.		large amounts necessary up to 5 litres per day

2.1.2 The need for a balanced diet

The food pyramid shown in figure 6.3 illustrates the approximate proportions of the different food groups which should be consumed in a balanced diet.

The foods in the lower part of the pyramid should form the main part of a balanced diet, while those at the top should be eaten in smaller quantities.

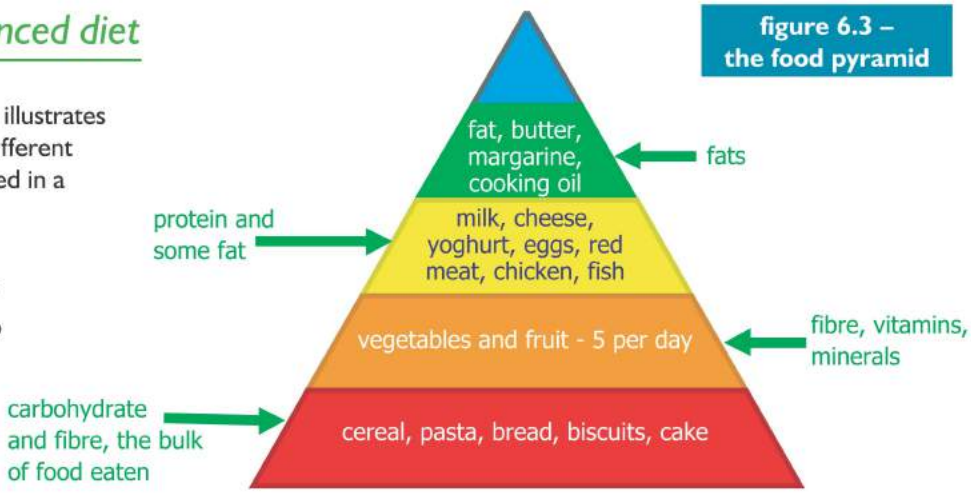


figure 6.3 – the food pyramid

Energy balance

When energy input is equal to energy output a **neutral energy balance** is achieved, as a result of which a person's weight remains constant. This concept can be expressed as:

ENERGY INTAKE = ENERGY EXPENDITURE

This means that there would be no tendency for this person to add adipose tissue to his or her body structure.

Positive energy balance

This definition of obesity highlights the major cause of obesity, namely an obese person would have energy intake far greater than energy output, which would be the result of inactivity and too much dietary fat intake.

This relationship is expressed as:

ENERGY INTAKE > ENERGY EXPENDITURE

to create a **positive energy balance**, which means that more energy is eaten as food than energy is used via exercise.

Excess carbohydrate (CHO) from food is stored as glycogen. When glycogen stores are filled, CHO together with excess fat intake are converted to fatty acids and glycerol, and then are stored as triglycerides or **fat** in adipose tissue. This is situated around major organs such as the heart and stomach, underneath the skin, and in skeletal muscle. Upper body obesity poses the most significant risk to disease.

Excessive weight gain is associated with certain health conditions such as **coronary heart disease** and **hypertension** (high blood pressure) with an increased risk of mortality and morbidity.

Controlling obesity

The only method of controlling obesity is to shift the energy relationship so that energy output exceeds energy intake – known as a **negative energy balance** and expressed as:

ENERGY INTAKE < ENERGY EXPENDITURE

This means that more energy is used via exercise than is eaten as food.

Questions

1) Define the term 'a balanced diet'.
2) Define the term 'energy balance'.
3) How can an understanding of the food classifications, illustrated in figure 6.3, assist in the maintenance an optimal weight for a sports performer?
4) How can energy balance assist in controlling obesity?

Achieving optimal weight for activities

The following table 6.2 shows how the body fat content for people of various age groups depends on whether they are fit or not. The data takes us up to 40 years of age.

Table 6.2 – **example data of relative body fat values for untrained and trained males and females**

	relative body fat (%)			
	untrained		trained	
age group	females	males	females	males
15-19	20-24	13-16	12-20	7-13
20-29	22-25	15-20	10-18	6-12
30-39	24-30	18-26	12-20	8-14

The achievement of optimal body mass will require manipulation of the **energy balance**. When energy intake and expenditure are balanced (**energy intake = energy expenditure**), an athlete's body mass will be stable, with no tendency to add to or subtract from stored adipose tissue.

Dietary requirements for exercise

Table 6.3 – **a comparison of daily energy intake for athletes**

activity	daily energy intake kJ – females	daily energy intake kJ – males
Tour de France		25000
triathlon	10000	20000
rowing	12600	14700
swimming	8400	15500
hockey	9200	13400
soccer	9600	14700
running	9200	13000
gymnastics	6000	9000
body building	5900	14500

STUDENT NOTE

Table 6.3 shows the variation in energy expended during competition and training (measured in kJ per day) in elite male and female endurance (figure 6.4), strength and team sport athletes. Except for high-energy intake of athletes at extremes of performance and training, the daily energy intake does not exceed 17000 kJ for men and 12500 kJ for women. Note that the difference between males and females can be accounted for by size difference. Values per kg of body mass would be similar.

figure 6.4 – endurance cyclists consume huge amounts of energy

Within rather broad bands, a balanced diet from a regular food intake provides the nutrient requirements for active individuals (as observed in the Food Pyramid figure 6.3 on page 77). However, dietary requirements depend on the **intensity** and **duration** of the exercise period. This means developing a diet that is tailor-made to suit the needs of the individual.

Carbohydrate requirements

Glycogen is the most important and most valuable food for any type of exercise. Physically active individuals should obtain between 60% and 70% of daily energy intake from carbohydrates – particularly unrefined, low glycemic foods such as fresh acidic fruits (apples, pears, oranges) and most vegetables. The longer the duration of the activity, the greater the % of CHO intake.

In activity lasting longer than 90 minutes, as in the case of marathon running, dietary manipulation techniques, such as **carbo-loading**, will increase muscle glycogen stores to above normal levels. Carbo-loading is a process where extra carbohydrate is taken in after a short period of carbohydrate starvation (see page 82 for further details).

Carbohydrate requirements

For rapid carbohydrate **replenishment** after exercise, carbohydrate foods with a high glycemic index are recommended, for example, foods such as bananas, brown rice, pasta, raisins or wholemeal bread. Food should be eaten within two hours of completing the physical activity. This is because eating these foods will be more efficient in increasing blood glucose concentrations and hence stimulating the greater insulin release needed to convert glucose to glycogen.
Optimal glycogen replenishment will benefit individuals involved in regular intense physical activity, such as playing in tournaments that span over a period of days.

Protein requirements

Physically active individuals need more protein than inactive people do (between 1.2-1.4 grams per kg body mass per day). Additional protein intake is needed to compensate for increased muscle breakdown that occurs during and after intense exercise. Protein is also needed to build new muscle cells (known as muscle hypertrophy).

In strength and power-based activities, additional protein intake is recommended (between 1.4-1.8 grams per kg body mass per day).

Fat requirements

Fat intake should be restricted, unless additional body mass is required, as is the case for extreme performers such as sumo wrestlers.
Unsaturated fats are preferable to saturated fats.

Vitamin and mineral requirements

Getting the right balance of vitamins and minerals can be sourced from the daily-recommended intake of fresh fruit and vegetables.

When and what should you eat before an exercise period?

- Food should be eaten between 3-4 hours prior to the competition so that it is well digested and absorbed into the bloodstream.
- The meal needs to be high in carbohydrates, low in fat and moderate in fibre to aid the digestive process.
- An example meal could be pasta bake with spinach, a banana and a still flavoured drink.

2.1.3 Hydration and electrolyte balance

Fluid intake has almost become an obsession with modern sportsmen and women. Modern athletes frequently use **isotonic sports drinks**, such as Isostar and Red Bull, just prior to competition to maintain rehydration and alertness respectively.

Exercise is thirsty work. Fluid loss during exercise depends on the intensity and duration of the exercise, temperature and humidity, body size and fitness levels. The longer and more intense the exercise period, for example in a long distance race, the more the need to drink before, during and after the event.

Bearing in mind that water comprises 60% of total body mass, it is important that **water balance** is maintained during exercise. **At rest**, water loss occurs via evaporation from the skin (sweat) and excretion with the majority lost as urine. Water intake will depend on climate and body mass. The modern fashion of carrying water bottles for ready consumption reflects modern concerns about water balance.

Questions

1) What are the three main groups of food?

2) Provide recommendations for carbohydrate, fat and protein intake for a cross-country skier and a ski jumper.

Hydration during exercise

figure 6.5 – Paula Radcliffe could be taking in water throughout a marathon

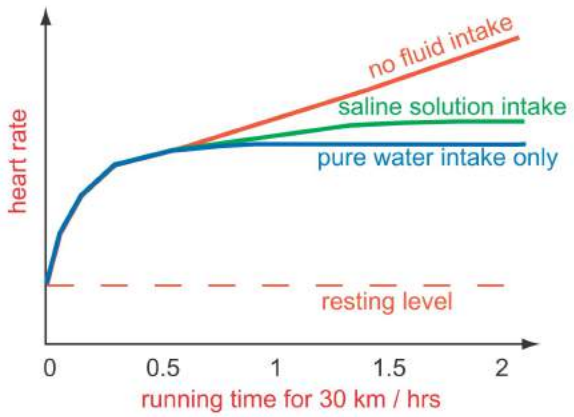
During exercise, more water is produced during tissue respiration along with heat energy as a by-product of the metabolic process. In order to prevent the body from heating up too much, water is transported to the skin where **sweating** occurs. The loss of water from the skin by **evaporation** causes the skin to fall in temperature, and hence reduces the effect of heat production in muscle. But far more water is lost as sweat than is produced by tissue respiration, the amount of sweat being determined by external temperature, body mass and metabolic rate. There is increased water loss via expired air due to increased breathing, but the kidneys decrease urine flow in an attempt to decrease dehydration. The total effect is that the body loses more water than is produced or retained, and this must be replaced if exercise is to continue at a maximal rate.

Loss of water

- Also, the loss of water raises the osmotic pressure in body fluids because the electrolytes become more concentrated in these body fluids.
- The thirst mechanism does not exactly match the body's hydration state, so more fluid should be consumed than thirst dictates.
- Only by **replenishing water** content can the electrolytes return to normal concentrations.

In extreme exercise situations (for example during a marathon, figure 6.5) 6-10% of body water content is lost, hence the need for water intake during exercise. This means that during 1 hour's exercise an average person could expect to lose around 1 litre of fluid, and even more in hot conditions. This could represent as much as 2 litres an hour in warm or humid conditions.

figure 6.6 – fluid intake during exercise



Dehydration and loss of performance

Excessive loss of fluid impairs performance as blood plasma volume decreases and body temperature rises. The graph in figure 6.6 shows how heart rate is affected by fluid intake during prolonged exercise. Heart rate rise without fluid intake is explained earlier, but the graph also shows how heart rate is kept constant - if suitable water is taken during the exercise.

The potential benefits of sports drinks

Sports drinks are designed to supplement energy, fluid and protein needs of the athlete.

When taken during exercise, **hypotonic** sports drinks are designed to quickly replace fluids lost through sweating as they are low in carbohydrates at around 4% glucose. They are very popular with athletes who need fluid without much carbohydrate. **Isotonic** sport drinks contain concentrations of salt and glucose (between 5-7%) that match the same levels of concentration as in the blood to maximise fluid intake and absorption. Both hypotonic and isotonic sports drinks are an important source of energy during exercise as they reduce the risk of dehydration.

During recovery, **hypertonic** drinks contain much higher levels of glucose - up to 20%. This highly concentrated drink is used to replenish depleted glycogen stores and should be drunk as soon as the exercise period has been completed.

Questions

1) How does dehydration affect heart rate, body temperature and exercise performance?`
2) Explain the importance of hydration to an active athlete.
3) How is body water balance maintained during prolonged aerobic exercise?
4) Distinguish between isotonic and hypertonic sports drinks?
5) What are the potential benefits of sports drinks?

2.1.4 - 2.1.5 The role and use of supplementation

figure 6.7 – sports supplements

Almost all modern sportspeople use sports supplements (figure 6.7) as part of their diet. Such supplements are aimed at filling the gaps in diet caused by inappropriate dietary content, or at enhancing features of food or drink taken which would be required to enhance sporting requirements for such a diet.

Creatine supplementation

Creatine is a substance found in skeletal muscle and which is stored as **phosphocreatine** (PC). Creatine (usually as Creatine Monohydrate) supplementation, together with large amounts of CHO, increases PC levels to enhance the ATP-PC system of ATP resynthesis, thereby delaying the alactic/lactic threshold (see page 73). This is a **legal ergogenic aid**.

Sportspeople use creatine in a way which will help improve anaerobic power and lengthen the time over which they can apply maximal power. It is not a muscle development 'drug', and eating lots of raw white meat (as in fish) would have the same effect. This is because white muscle cells (those not containing lots of myoglobin, which is red in colour and is present in large quantities in slow twitch muscle cells) are predominantly fast twitch in nature and contain creatine in relatively large quantities.

Power athletes, such as the pole vaulter lifting weights in figure 6.8, use in their competitive event a little bit of the ATP-PC system and mostly ATP storage. But almost all the training will be serviced by the ATP-PC system, and therefore creatine supplementation will help the training process.

figure 6.8 – power athletes benefit?

Creatine supplementation can cause muscle cramps, can be responsible for athlete weight gain, and can cause heat-related disorders such as dehydration and renal stress.

Protein supplementation

Many athletes regularly consume sports drinks that are designed to supplement the energy, fluid and protein needs of the athlete. Protein supplements, such as **whey protein**, are used to increase total protein content of an athletic diet. Sportspeople need more protein than the untrained person to enable muscle hypertrophy and muscle repair following hard training. This particularly applies to sports requiring large muscle mass, as in weight lifting and gymnastics.

Within the section on the Athlete's diet on page 84, a protein shake is recommended as an important protein supplement for a female 800 metre athlete, particularly following a high intensity training session.

- A controversial area of research is whether there is need for protein supplementation. This is particularly if the athlete is already consuming a balanced diet that meets all his or her nutritional requirements. If this is the case protein supplementation becomes a very expensive form of energy food.
- Most protein supplements are legal, but can cause liver and kidney damage if taken in excess.
- **Glutamine** is an **amino acid** forming part of **skeletal muscle** and **immune cells**. Supplementation after exercise therefore reinforces the immune system and **reduces the risk of infection** and therefore enhances the process of glycogen synthesis in recovering muscles. Glutamine supplementation is widely used by athletes.

Questions

1) What is creatine?
2) What type of athlete would benefit from taking a creatine monohydrate supplement?
3) Identify the advantages and disadvantages of using a creatine monohydrate supplementation?

Herbal remedies

Herbal remedies are derived from plant extracts and are part of the practice of homeopathy and are in the form of tablets, oils or creams and liquids. Intake of a broad range of herbal supplements for ergogenic purposes has expanded considerably over the past decade. Examples include:

- **Ginseng**, which is reported to increase mental alertness, boosts energy levels and the immune system, increases $\dot{V}O_{2max}$, and reduces OBLA. The controversial use of ginseng was popularised by Chinese women endurance athletes in the 1990s. Little evidence exists to support the effectiveness of ginseng as an ergogenic aid.
- **Glucosamine** is known to reduce joint inflammation and stiffness.
- **Arnica** is used to reduce inflammation, bruising and pain.
- **Camomile** is known to reduce stress, support the immune system, promote tissue repair and assist sleeping.

Many herbal remedies for common conditions such as colds, flu and bronchitis are used to avoid restrictions imposed by doping regulations. This is because there are substances commonly used in the pharmaceutical versions of such remedies, such as codeine or ephedrine, which are against doping regulations. However, care needs to be taken when using herbal remedies since some herbal remedies contain substances on the doping register.

Bicarbonate use

Bicarbonate loading is a process whereby a performer ingests bicarbonate prior to a competition. An athlete can increase plasma bicarbonate levels that provide additional **buffering capacity**, thus allowing higher concentrations of lactate in the blood. Theoretically, this could delay the onset of fatigue in all-out anaerobic activity such as a 400 metre race. Bicarbonate loading can cause cramping, vomiting, bloating and diarrhoea.

Caffeine

By drinking a large black coffee one hour prior to activity, caffeine can produce significant increase in specific power output for all fibre types during both anaerobic and aerobic exercise, thus improving fatigue resistance during the performance. Consuming too much caffeine leads to a drop in performance for endurance events, such as a marathon race.

- Caffeine **stimulates** the central nervous system thereby reducing reaction times.
- Caffeine acts as a **diuretic**, which can lead to dehydration and heat related conditions.
- Caffeine used to be illegal in large quantities, but the rules changed in 2002, making this **legal** again!
- Caffeine is also used to promote **fat metabolism** and hence to reduce adipose tissue in the elite sportsperson.
- Consuming caffeine before prolonged exercise increases fat metabolism thus **sparing** precious **glycogen reserves** for later.
- Caffeine produces a state of **nervousness**, and can disrupt normal sleeping patterns therefore contributing to fatigue.
- Abrupt ceasing of caffeine intake can lead to severe headaches.

Alcohol

Alcohol is a relaxant in quite small quantities. It is absorbed into the body as an alternative to water therefore causes dehydration. Quite small quantities of alcohol can cause a drastic loss of performance. Alcohol is a **legal** ergogenic aid - but anyone using it as such must be aware of the consequences!

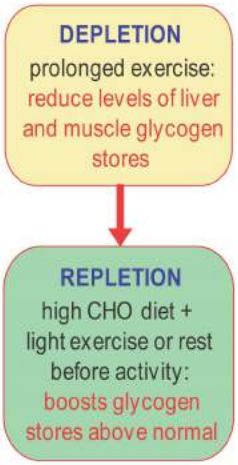
2.1.6 Strategies for optimising food fuel intake

Carbo-loading

Carbo-loading aims to raise muscle glycogen stores above their normal resting levels prior to endurance competitions with over 90 minutes continuous activity. This process is suitable for activities with low anaerobic and high aerobic components.

Figure 6.9 outlines the **depletion-repletion** model upon which carbo-loading is based. It is suitable for any activities lasting longer than 15-20 minutes. Note that a two-day high CHO diet beforehand provides the best CHO boost for an endurance event.

figure 6.9 – carboloading



Carbo-loading - glycogen supercompensation

The graph in figure 6.10 (see page 83) shows how the muscle glycogen level returns to above normal values when the **depletion-repletion** process is undertaken as outlined in the previous paragraph. In effect the body reacts to a loss of glycogen by vigorously replacing it to a level above normal. This is a normal reaction to **biological stress**.

Pre-competition nutrition

Should consist of:

- Fluids for hydration.
- Light complex CHO such as pasta or wholemeal bread at least 3 hours before activity.
- Fruit (banana) contains complex CHO.
- Small amounts of glucose.

The effect is to provide the slow release of blood glucose and reduce hunger sensations.

Post-competition or training nutrition

Should consist of:

- **Hypertonic** sports drink immediately after exercise has finished.
- This begins **replenishment of blood glucose** and **glycogen** stores.
- A **high CHO** meal within 15 minutes of exercise ending (or as soon as possible) continues glycogen replenishment.

The importance of high glycogen content in muscle before a marathon race

The graph in figure 6.11 shows that a runner's time would increase by around 10 minutes in a 2 hour run if muscle glycogen started at 50% of its maximum possible. The effect of reduced muscle glycogen begins to be felt at the 1 hour mark. Hence the importance of glycogen loading to endurance sportspeople.

figure 6.10 – glycogen supercompensation

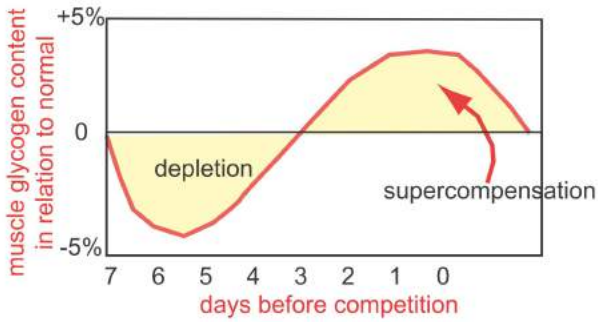


figure 6.11 – effect of glycogen store on endurance running times

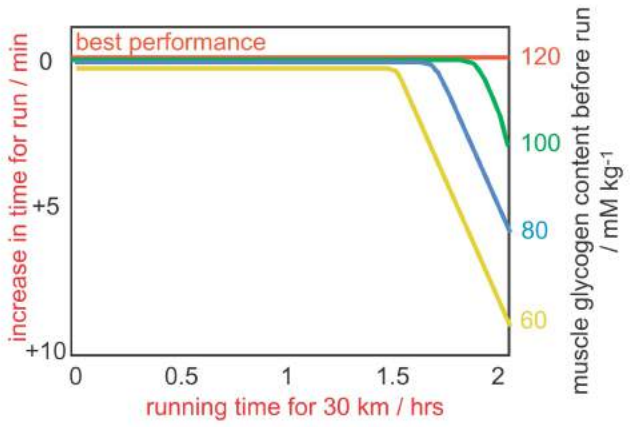
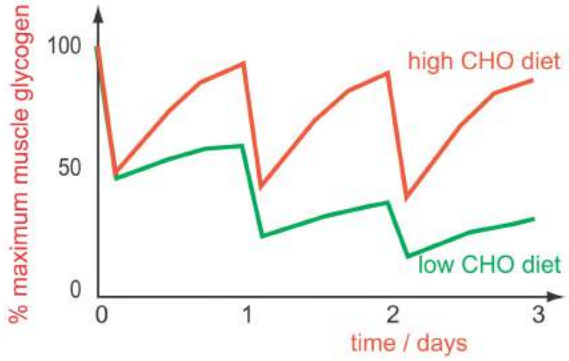


figure 6.12 – the athlete's diet



Nutritional dietary manipulation during training

The graph in figure 6.12 shows the influence of dietary carbohydrate on **muscle glycogen** stores. In this training situation, repeated daily exercise of 2 hours is followed by either a high CHO or low CHO diet.

STUDENT NOTE

Note the difference that high CHO makes to the energy available to the sportsperson, and a major possible reason for exhaustion for those 'on a diet'!

Questions

1) Figure 6.12 shows the influence of dietary carbohydrate on muscle glycogen stores. Give examples of types of food that are high in carbohydrates.
2) What is meant by the terms depletion and repletion within the concept of carbo-loading?
3) What are the benefits of taking a sports drink immediately after exercise?

Case study of an elite athlete

So how does an elite athlete assess whether their diet meets the demands of their training and competition programmes? A qualified nutritionist normally undertakes a nutritional assessment of the athlete's current diet:

- The athlete will undertake a detailed dietary log containing all food eaten (including food portions) during a selected period of time.
- He or she will answer a questionnaire about food habits and training issues, such as symptoms of fatigue that may be due to poor nutrition.
- Analysis of training and competition demands.
- Body mass assessment to work out BMR.
- Body composition to assess ideal body weight (many female endurance athletes suffer from anorexia nervosa).

Additional assessments may include:

- Blood samples to test for iron deficiency anaemia. Female athletes are particularly vulnerable to low haematocrit levels.
- DEXA scan (DEXA stands for 'dual energy x-ray absorptiometry') to measure bone density. In general, the more dense the bone, the stronger it is, and the less likely it is to break. Dietary calcium is needed to maintain bone density levels.

Once a dietary assessment has been completed, a tailor-made diet can be created that meets the specific energy and dietary requirements of the athlete.

Summary of the nutritional recommendations for an elite female 800 metre athlete

Body fat and weight are fine – any slight increase in body weight must be muscle gain and not fat (her body fat was measured at 9%).

The food choices in table 6.4 below aim to keep body fat low. Low GI (glycaemic index) carbohydrate intake should be considered, and a focus on protein-type foods supplemented by fresh vegetables and fruit. Notice also that snacks between the 3 main meals aim to top up the ever-depleting energy reserves and so aid recovery following training sessions.

Table 6.4 – **dietary suggestions for elite endurance runner**

	dietary suggestions for elite endurance runner
1	**breakfast** – include some protein (yoghurt, eggs) and carbohydrate (cereal, porridge and wholegrain toast)
2	**mid morning snack** – banana and water, cordial are fine
3	**lunch** is not enough - need cooked meal such as pasta or rice or potato dish with some form of meat, fish, salad + yoghurt and fresh fruit, in place of sandwiches
4	**afternoon snack** – suggest a protein shake
5	immediately after training go for a Yazzoo or Smoothie or protein shake
6	cooked **evening meal** with meat, fresh vegetables, yoghurt, fresh fruit, water
7	**light night-time snack** such as Carb Sense bar or porridge, muesli, water
8	more fluid should be consumed than thirst dictates
9	increase CHO intake 36 hours prior to competition date
10	need daily **supplements**: glucosamine and chondroitin for joints, 1 x multivitamin a day, 1 x 100mg of omega-3 fatty acid a day

Vegetarian athletes should give careful consideration to selecting plant foods that provide a good balance of the essential amino acids (such as beans, lentils, quorn, soya and tofu), sufficient calories and adequate sources of vitamin A, riboflavin, vitamin B12 (dairy products), vitamin D, calcium, zinc and iron (dark green leafy vegetables).

Exam style questions

1) Figure 6.13 shows the daily energy intake (kjoules) of elite male and female endurance, strength and team sport athletes.

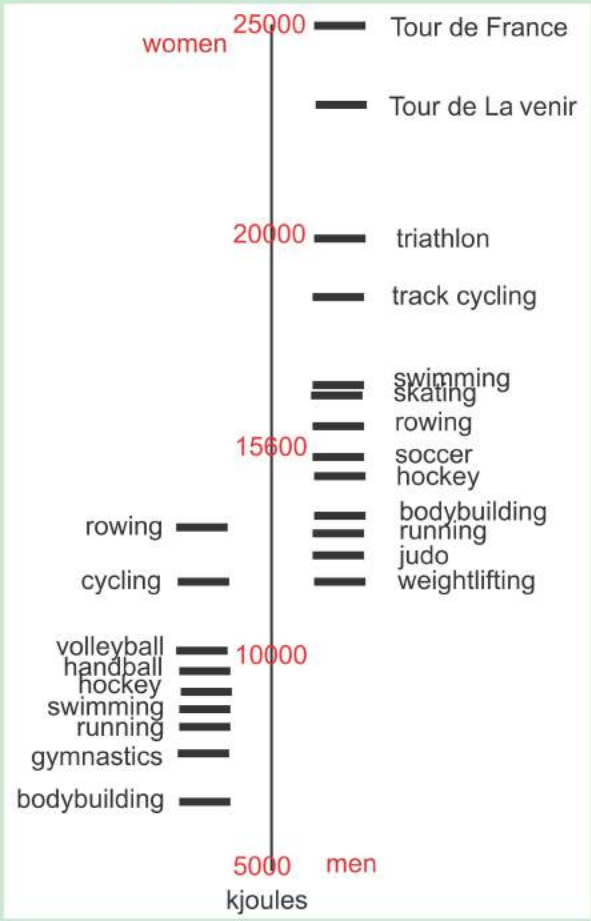
   a) Account for the differences in the daily intake for males and females. 2 marks

   b) Give reasons why cyclists competing in the Tour de France require a daily intake of up to 25000 kjoules. 3 marks

   c) Why do female body builders have the lowest daily energy intake compared with other female sportspeople? 2 marks

   d) How can a negative energy balance ultimately compromise an athlete's potential to train and compete? 3 marks

figure 6.13 – daily energy intake for elite athletes



2) The ideal precompetition meal should maximise muscle and liver glycogen storage and provide glucose for intestinal absorption during exercise. How can these goals be achieved? 4 marks

3) An athlete is competing in a decathlon (consisting of 10 track and field events) over a period of two days.

   a) What nutritional advice would you give this athlete during and between the events in order to achieve an optimal performance. 6 marks

   b) At the end of day one, how could this athlete replenish his glycogen reserves? 4 marks

4) Identify some of the benefits of taking commercially prepared liquid meals. 3 marks

5) Table 6.5 provides information on exercise intensity and duration. Information on the appropriate fuel foods for action has been omitted.

Table 6.5 – **fuel and exercise**

exercise intensity	exercise duration	fuel used
maximal sprint	**short**	
low to moderate	**moderate - up to 2 hours, eg jogging**	
severe	**prolonged - eg cycling**	

   a) Complete the third column to show which fuel foods supply the glycogen needed as exercise intensity and duration change. 3 marks

   b) Why is carbohydrate a much faster fuel (energy) source when compared with fat utilisation? 2 marks

   c) High-fat diets, as an ergogenic strategy for sports performance, have been used by athletes for endurance and ultra-endurance sports. Discuss. 6 marks