Endurance for MASTERS

Bruce Tulloh

PEAK PERFORMANCE
The research newsletter on stamina, strength and fitness

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About the Author

Bruce Tulloh is better qualified than most to write about endurance for Masters. In 2007 he celebrates the 60th anniversary of winning his first race (as a 12-year-old school boy). Every year between 1958 and 1967 he either won a national title or broke a national record, or both. He was European champion at 5,000 metres in 1962, set British and European records at two miles, three miles and six miles, and in 1969 completed one of the ultimate endurance tests by knocking eight days off the record for the 3,000-mile run from Los Angeles to New York. He went on winning races until his late 40s, set age-group records in his 50s and ran a half marathon in 76 minutes at age 60. He continues to run 30 miles a week and still races occasionally.

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Chapter 1

What is endurance?

The term is used so widely that we imagine we understand it, yet it varies according to the context in which it is used.

Endurance in the broadest sense means going on doing what you are doing at the same intensity for a bit longer.

An endurance sport is one in which the effort is not flat-out and the event is of long duration. But when it comes to defining long duration, there is a great deal of variation between sports.

- *In swimming* 800 metres would be considered an endurance event;
- *In running* 3,000m might be considered an endurance event – and the term would certainly apply to races of 5000m and over;
- *In cycling* 10 kilometres certainly entails a degree of endurance, but the distances covered in this sport are so great that some would reckon 10 miles to be the shortest event requiring endurance.

What does endurance mean in terms of team games such as football? While the bursts of intense effort are very short, players cover many miles in the course of a game. For them, endurance means being able to carry on performing well right through the 80 or 90 minutes, and into injury time if necessary. It also means having the 'all-round fitness' to turn out for two or more matches a week right through the season.

Endurance is sometimes taken to mean 'consistency'. In this context it means remaining fit, uninjured and enthusiastic year after year.

This definition of endurance will have a particular resonance for older players, who are seeking to prolong their active careers for as long as possible.

It is self-evident that the longer the duration of your event, the more important is your capacity for endurance, while your natural skills become relatively less important. This is a good thing for older athletes, since it gives us a chance of beating younger performers who lack either the time or the inclination to put in the necessary endurance training.

A more rigorous definition of endurance might be 'delaying the effects of fatigue', or 'being able to cope with fatigue'. With fast bowling, for example, each individual effort is an explosive one, but the bowler needs endurance to carry on making these efforts all day long. This is clearly a different kind of endurance to that needed by the long distance runner or cyclist. For the bowler it is more about fitness – *ie* how well he recovers after each delivery. But it also includes other factors, such as his efficiency of action. The older bowler may be able to go on for longer simply because he has become more efficient and so does not tire himself as much on each delivery.

"A more rigorous definition of endurance might be delaying the effects of fatigue"

Types of endurance

So at this early stage we can already divide our topic into several component parts, which will be considered in more detail later in this chapter:

1. ***Pure endurance*** This means the ability to continue at a set pace and relies on such factors as fuel consumption, muscular fatigue and heat tolerance, as well as mental strength;
2. ***Powers of recovery*** This is related to fitness, which depends on oxygen intake and muscular strength;
3. ***Efficiency*** This has a considerable effect on your powers of endurance. To take a crude example, if a man climbed a rope using his arms only, he would not last as long as someone who was also using his legs!

Before we go on to consider how we can build, maintain or enhance our capacity for endurance, we need to understand the mechanisms involved in all physical movement in general, and endurance activities in particular.

The Muscle engine

We have about 600 muscles in our body, and most of these are in use when we are moving, either actively in moving a bone, or *passively* in holding the skeleton rigid. Muscles are usually arranged in pairs which work against each other, so that when one of the pair contracts the other has to relax and be stretched. The muscle itself is made up of bundles of muscle fibres containing 'myofibrils' made of protein filaments.

Muscle contraction is initiated by a nerve impulse from the brain or the spinal cord. In response to this stimulus, cross-bridges are formed between the adjacent protein filaments, causing the fibres to contract.

Any muscular contraction, whether active or static, requires energy, and this comes from the breakdown of adenosine *tri*phosphate (ATP) to adenosine *di*phosphate (ADP) plus a phosphate ion. ATP is continually regenerated by little 'powerpacks' called mitochondria, which lie between the myofibrils.

Energy sources

The ATP contained in human leg muscle is only enough to power one second of maximum effort, so it has to be constantly regenerated. There are two sources of stored energy in the muscle that can be used for this purpose: phosphocreatine (PC) and glycogen. Even a well-trained sprinter has only enough PC to last a few seconds. However, research has shown that glycogen and PC are used simultaneously during maximum effort, so the PC lasts for about 20 seconds.

Glycogen, sometimes called 'animal starch', is made up of chains of glucose units and is stored in the muscles and the liver. During exercise, enzymes are released which break down the glycogen and feed glucose into the bloodstream. The total amount stored provides enough energy for less than two hours of maximum effort, which explains why the marathon distance is so demanding.

'Eventually the build-up of acidity will stop the muscle from working'

Aerobic and anaerobic respiration

The glucose can be used by muscle fibres in two ways: for anaerobic or aerobic respiration. Aerobic respiration is the most efficient process because it produces 12 times more energy per molecule of glucose than anaerobic respiration; but it is also a more lengthy process and depends on the availability of oxygen.

Anaerobic respiration needs no oxygen and so can take place instantly. The drawback is that lactic acid, the by-product of this process, accumulates in the myofibrils, eventually inhibiting further contraction. This lactic acid mostly exists as lactate and hydrogen ions; and it is the hydrogen ions (also called protons) that increase the acidity in the fibres, causing a lot of pain in the muscles that are working hardest.

The blood contains substances known as 'buffers', which combine with the protons and so limit the rate at which acidity increases; but eventually the build-up of acidity will stop the muscle from working.

Oxygen debt

Lactic acid that accumulates in muscle is removed with the help of oxygen, which breaks down the lactic acid to carbon dioxide and water. The volume of oxygen required is known as the 'oxygen debt'.

Once the duration of the maximum effort goes beyond 10 seconds, anaerobic respiration is no longer sufficient and energy is needed from other sources. Aerobic respiration is 'safer' for the muscle fibres than anaerobic respiration because the by-products of glucose breakdown are just carbon dioxide and water.

Acids in the body

Chemists measure acidity on the pH scale, which runs from 1 to 14. 1 means a completely acid environment, 7 means 'neutral' and 14 means a completely alkaline condition.

The stomach wall secretes a strong acid, so the pH of the stomach contents is low, but this is neutralised by substances produced in the small intestine. Blood plasma is normally close to pH 7, but carbon dioxide released by respiring cells forms a weak carbonic acid, and lactic acid from anaerobic respiration will also lower the blood pH.

The blood contains 'buffer' substances which can soak up or release protons, thus keeping the pH fairly constant. When fats are broken down, they form 'fatty acids', but these are very weak and have no effect on the pH of the blood.

The need for oxygen

Because oxygen is needed for aerobic respiration, the rate at which energy can be produced depends on the rate at which oxygen can be supplied. This in turn depends on the effectiveness of your cardiovascular system – the heart, blood vessels and lungs. The more rapidly blood can be pumped, the faster oxygen can be picked up in the lungs and carried to the muscles, and the faster the carbon dioxide can be carried away.

How much energy do we have?

We have enough stored glycogen to cope with normal daily activity, with around 500g stored in muscle and another 100g stored in the liver. However, an elite male marathon runner running at five-minute-mile pace will use up glycogen at the rate of 5g per minute, or 25g per mile (15g per kilometre). At this rate, the total store of 600g would be completely used up by 24 miles, even assuming that all of it could be made available. Since the brain cells rely exclusively on glucose, the runner would collapse when the level of blood glucose ran low.

In addition to glycogen, we have a huge amount of energy stored as body fat – enough to run for hundreds of miles and survive weeks of starvation. In our normal daily activities we rely mainly on this fat as our source of energy. The fat is broken down into smaller chains called fatty acids, and these are respired with the use of oxygen.

Metabolising fatty acids requires more oxygen than when glucose is the fuel, so fats cannot be used when are moving fast; this can be seen in marathon running, when those who have started too fast run out of glycogen. We may use up glycogen in short bursts of energy, but we keep our stores topped up by eating regular meals.

Sports which alternate between high and low intensity effort are relatively economical in their use of precious glycogen. It is only in the sports demanding continuous effort that fuel supplies affect performance.

Table 1: Event duration and percentage contribution of energy sources (1)

Event duration	Energy source			
	PC	Glycogen anaerobic	Glycogen aerobic	Fats
< 15secs	50	50	-	-
< 30secs	25	65	10	-
< 60secs	12.5	62.5	25	-
< 2mins	6	50	44	-
< 15mins	-	3	97	-
<2hrs	-	-	80	20
>5hrs	-	-	40	60
Football game	10	70	20	-

Table 1 shows how it is possible to define sports on the basis of their fuel consumption: in those which require more than two minutes but less than two hours of continuous hard effort, aerobic fitness – *ie* the ability to take in and use oxygen – is by far the most important factor in determining endurance, but in sports lasting five hours or more, where more than half the energy is derived from fats, it is less important.

The percentages for football are highly significant. Because the efforts are not continuous, 80% of the energy expended comes from anaerobic sources. Team sports like football and those which include regular stoppages, such as tennis, do not really qualify as 'endurance sports' in terms of fuel consumption. They do demand endurance in terms of aerobic fitness, though, and for long matches players also rely on other elements of endurance, such as temperature control and mineral balance, of which more later.

The importance of 'pure' endurance

We now have a clearer idea of what is meant by 'pure' endurance. It means the ability to go on working for hours at a slow speed, or with alternating periods of high level and low level activity. If the pace is slow, most of the energy will come from fats – and a kilogram of fat provides enough energy to run for 50 miles or cycle for over 100. Moreover, in a slow-paced event it is possible to take in high carbohydrate drinks on the move. Since speed is less important for these types of events, older athletes are not handicapped by lack of pace and may have better capacities for metabolising fatty acids than their younger counterparts.

Another key factor here is heat tolerance. The longer the event, the more heat is generated by the muscles, and this has to be lost through the skin, mostly by sweating. If the core temperature of the body builds up, the oxygen cost of the activity increases, so the heart rate goes up. It may be, therefore, that the athlete who is more efficient at temperature control will perform better than a faster performer who cannot handle heat.

Another factor in 'pure' endurance is the build-up of fatigue-causing chemicals in the brain. During prolonged exercise there is a rise in levels of the amino acid tryptophan. In the brain this is converted into 5-hydroxytryptamine (5HT), which causes tiredness. The greater endurance exhibited by some older and more experienced athletes may be because they produce less tryptophan or because they can metabolise it more efficiently.

Powers of recovery

The reason why one sportsman outlasts another may simply be down to a higher level of fitness, leading to enhanced recovery. If two squash players, for example, are running about the court at the same pace, the fitter one will be less out of breath after each rally. The unfit player, with a lesser capacity for taking in oxygen, has to keep on panting in order to pay off his oxygen debt, so his heart and lungs have to work a lot harder. The fit player will have a lower heart rate at the end of each rally and will recover more fully between rallies. Regardless of age, aerobic fitness, in term of oxygen capacity, is a decisive aspect of endurance.

The different types of muscle fibre

Your performance under stress, and the fatigue you suffer as a result, will vary considerably according to your physical type and condition. There are five types of muscle fibre, of which three are found in our working muscles; (the other two are heart muscle, which – fortunately – keeps on working non-stop, and involuntary or 'smooth' muscle, which is found in the walls of the stomach and intestine).

The three types of muscle fibre are:

- slow twitch (ST);
- fast twitch (FT) glycolytic;
- fast twitch oxidative.

Slow twitch muscle fibres prefer to generate their energy by aerobic means. As their name implies, they do not contract fast; however, they are able to carry on working for a long time before tiring. They have a rich blood supply to provide them with the oxygen they need. The fibres themselves are quite small, and so are the motor units (bundles of fibres) they help to make up.

Fast twitch oxidative fibres are larger than ST fibres and can generate their energy either aerobically or anaerobically. They contract at a much faster pace than ST fibres.

Fast twitch glycolytic fibres are even larger than the oxidative type and prefer to generate their energy anaerobically, using glycogen rapidly, contracting fast and generating speed.

It is said that sprinters are born rather than made and this is true in the sense that the leg muscles of a successful sprinter will contain mostly (75-80%) FT fibres, while those of a marathon runner will contain the same proportion of ST fibres.

The impact of training

However fibre type can be modified by training. Middle distance runners, who normally possess FT and ST fibres in equal proportions, can adapt their muscle type so that they can move into either long distance running or sprinting. One research team working with distance runners found that after 18 weeks of endurance training their muscles were made up of 69% slow twitch fibres and 31% fast twitch (2). The same group then completed 11 weeks of sprint training, after which the ratio of fibres had changed to 52% ST, 48% FT.

'Middle distance runners can adapt their muscle type so that they can move into either long distance running or sprinting'

Anecdotally, I know of many international athletes who have successfully moved either up or down in distance. The New Zealander Rod Dixon, a world-class 1,500m runner, moved up in distance with such success that he won the New York Marathon. On the other hand, Sebastian Coe, who won national under-15 titles at 1,500m and 3,000m, worked hard on his speed to turn himself into a 46-seconds 400m runner and world record-holder at 800m. It was this acquired speed that enabled him to become the double Olympic champion at 1,500m in 1980 and 1984.

To take a couple of even more extreme examples, the Finnish runner Juha Vaatainen represented his country over 100m as a Junior (with a personal best of 10.8secs) and some years later won the European titles at 5,000 and 10,000m, while British sprinter Todd Bennett started off as a cross-country and middle distance runner at school and ended up as a European medallist over 200m.

The different components of endurance

There are seven main components of endurance, which are required to a greater or lesser degree in different sporting situations. These are:

1. lactate tolerance
2. specific muscular endurance
3. aerobic fitness
4. efficiency
5. temperature control
6. fuel supplies
7. mental strength.

Endurance 1: lactate tolerance

This is the ability of the body to keep working when lactic acid or protons build up in the muscles and the blood (*see page 10*). This type of endurance is important in situations where a flat-out effort is needed continuously for more than 10 seconds but less than 10 minutes. It is most likely to come under strain in longer events when a hard effort is called for – such as during the uphill phases of a cycle race, the last 500m of a rowing event or the last lap of a track race.

When I say 'hard effort', I mean that the rate at which energy is being expended exceeds that which can be obtained through aerobic respiration. The anaerobic breakdown of glucose produces lactic acid. If the effort lasts more than, say, five minutes, oxygen consumption will have reached its maximum and can go no further. As the effort continues, the rising tide of protons starts to inhibit muscle contraction and the effort becomes more and more painful. The visible signs of this conflict are laboured breathing and the loss of a smooth action as some of the muscles start to fail.

Some improvement in lactate tolerance can be brought about by training. Event specific training that combines elements of both speed and resistance work (*see Chapter 5*)

increases the ability of the muscle fibres to go on working in acidic conditions by enhancing their buffering capacity.

For older athletes, with years of training behind them, it is more about maintaining muscle strength and blood circulation than developing them, but training must still be regular, as explained in Chapter 5.

Lactate tolerance can also be improved, to some extent, through sheer motivation. An experienced athlete can continue to work hard even when lactate levels are rising because he knows the pain will be short-lived.

Dietary ways of improving lactate tolerance, by ingesting alkaline substances, have not proved effective, since the pH of blood plasma is maintained at a constant level.

Endurance 2: specific muscular endurance

This means endurance in a small group of muscles rather than in the whole body. If a tennis player practises a forehand volley over and over again, his arm will eventually become tired. And a young player will tire more easily than a tournament professional. Why does the arm tire when the body has enough fuel for hours of effort, the player's oxygen consumption is well below its maximum and his heart rate, if monitored, would be found to be well within safe limits?

The most important factor in muscular endurance in this example is the strength of the arm. The more muscle fibres there are, and the bigger they are, the easier it will be to play the shot. Muscle contraction relies on the use of ATP, which has to be regenerated. It the arm is strong enough, only half the muscle fibres in it need to be used at any one time. This leaves the rest free to regenerate their ATP via their stored phosphocreatine, which is, in turn, regenerated by breakdown of glycogen (glycolysis), with lactic acid as a by-product. It is also important to note that larger muscles have larger glycogen stores.

There is some overlap here with the 'lactate tolerance' element of endurance, because accumulating lactic acid will cause fatigue unless it is removed. That's where the circulatory system comes in: if the arm has a rich blood supply, the oxygen carried in the blood simply 'burns off' the lactic acid, allowing the player to carry on playing shots indefinitely. And we do know that systematic training over many weeks boosts the blood supply to muscles, as well as increasing their strength, their power and hence their endurance.

Other reasons why muscles tire

The reason why the arm tires in the example given above is partly to do with the nervous system. It is possible that when playing very rapid shots – *eg* in table tennis – the muscles may not be able to pass on the stimulus to all the relevant fibres, so that an insufficient number are brought into play ('recruited') to perform the necessary contraction.

Immediately after the shot, the arm action is reversed and muscles that were contracting are asked to relax and stretch. To some extent, the flexibility of the muscles and the mobility of the joints involved in switching between contraction and relaxation affects the speed of the shots. A well co-ordinated player will play more economically (*see page 21*) and thus tire more slowly. In addition, the speed of muscle contraction can be adversely affected by the loss of fluid and salts in sweat.

> *"A well co-ordinated player will play more economically and thus tire more slowly"*

All these factors can be modified by practice. Older players should be more economical than youngsters, but will lose flexibility and joint mobility unless they work on these qualities in training.

In this context, it is important to note, though, that strength training a particular group of muscles will increase their *bulk* as well as their strength. And while the larger muscles are able to store more fuel, their increased bulk will restrict the amount of blood flowing around the fibres.

Less intense training, using lighter weights for longer durations, will not boost strength to the same degree but will boost the number of small blood vessels known as 'capillaries' within the muscles, while also facilitating an increase in the number of 'mitochondria' – the structures responsible for energy production within cells.

Training schedules for specific disciplines must balance the need for strength against the need for a good oxygen supply.

Endurance 3: aerobic fitness

This means the ability to take in and handle oxygen. It is measured universally in terms of 'maximum oxygen intake', known as VO2max, and the units are millilitres of oxygen per kilogram of body weight per minute. A VO2max of more than 70ml/kg/min for a man is a sign of international potential in events like running, cycling and swimming. The equivalent figures for women are generally 10% lower. World-class male athletes have VO2max measurements in the 80s, while those of good club performers are in the 50s and 60s.

Like muscular strength, VO2max declines steadily with age from the mid-30s onwards, at a rate of 0.5-1% per year.

This type of endurance matters in events where you are working at, or even slightly above, your maximal oxygen consumption. Generally speaking, the higher your VO2max the better you will perform, but other factors come into the equation. For example, a runner in a 5k race – an effort lasting roughly 15 minutes – will be running at 90- 95% of his VO2max. The more economical he is (*see page21*), the closer he can get to his VO2max before his blood lactate levels start to rise.

What determines your VO2max? To a large extent it depends on the strength and capacity of your heart. As your heart pumps blood through your lungs, the haemoglobin in the red blood cells soaks up the oxygen, becoming fully saturated in the few seconds that it is circulating in the lung membranes. Lung size or chest size rarely affects the rate of oxygen uptake: what matters is the capacity of your heart and circulatory system to pump the blood.

If you are anaemic – *ie* lacking haemoglobin – you will not be able to take up as much oxygen. Conversely, if you have more blood cells, and therefore more haemoglobin, your oxygen uptake will be increased. This can be achieved legitimately by means of altitude training or illegitimately by 'blood doping' or dosing yourself with erythropoietin (EPO), a hormone that boosts the number of red cells.

Age and VO2max

As you get older, the elasticity of your heart diminishes and with it your maximum heart rate. The rule of thumb is that your maximum heart rate, in beats per minute, is 214 minus (0.8 x age), but consistent training slows the decline.

In any case, when adopting 'ready-made' training schedules from a book, it is advisable to check your real heart rate rather than relying on an estimate.

Other things being equal, the greater your aerobic fitness the less stressed you will be in a strenuous sport and the greater will be your endurance. To take running as an example, a man who has been used to running training miles in under four-and-a-half minutes is going to feel comfortable running at five-minute pace in a race. Thus, working on VO2max, as described above, will form a large part of his training.

For team players, the fast runs in attack or defence may last only a few seconds, but they have to be repeated with little recovery, so fitter athletes will be able to play at a faster pace throughout the game than their less fit counterparts.

Endurance 4: efficiency

The runner with the greatest oxygen-processing capacity will not necessarily win the world 10,000m title, just as the rower with the greatest power output is not certain to win the Diamond Sculls at Henley Regatta.

For every event there is always a skill factor. This is particularly obvious in one-on-one sports, such as tennis and squash, where skilful players clearly need to work much less hard than those with lesser skills; but the same rule applies in every sport.

In terms of endurance sport, nowhere is the importance of the skill factor more in evidence than in cross-country skiing. Children brought up in Alpine or Nordic countries start skiing as soon as they start walking; consequently, those with natural ability select themselves for the sport very early, and by the time they reach Olympic level have had 20 years-or-so to sharpen their skills. These events make higher demands on oxygen intake than any other sport (with the possible exception of rowing, which also involves many different muscle groups), so high VO2max is essential. However, competitors from Kenya and Ethiopia, who have very high aerobic capacities, consistently finish 15 minutes or more behind over the 30k distance simply because they lack the requisite skills.

The relevance of this example for older performers should be clear: improving your skills can compensate for declining fitness. The secret of success in endurance events is first to choose the sport or the event for which you are best suited and secondly to analyse your strengths and weaknesses in order to hone your skills.

Economy and efficiency

When we talk about 'economy of effort' in sport performance, we mean achieving a certain power output with as little wasted energy as possible. Whether your performance is limited by the amount of oxygen you can process or by fuel supplies, you are bound to gain by becoming more economical and therefore more efficient.

The longer the duration of your event, the more important economy becomes, the relevant factors being:

- your build, in biomechanical terms and
- the technical skills you have acquired with practice.

'Improving your skills can compensate for declining fitness'

Over a prolonged period of training, an athlete will grow in fitness as well as efficiency, so it is hard to identify the precise reasons for improved performance. When I was working with Richard Nerurkar, once Britain's top marathon runner, we had his VO2max measured regularly at the British Olympic Medical Centre. From the age of 26, when he was running internationally at 10,000m, to his retirement eight years later, his VO2 did not vary greatly – usually around 84 ml/kg/min – but his marathon performance improved from an initial

Some definitions

- ***Power*** is the rate at which work is performed. It is measured in watts.
- ***Efficiency*** relates to the amount of fuel and oxygen needed to perform a given amount of work. In cycling, for example, a particular gear ratio will give maximum efficiency for travelling at a particular speed. External factors, such as heat and humidity, may impair an athlete's efficiency.
- ***Economy*** relates to the way an athlete's movement contributes to greater efficiency. Poor economy is the same thing as wasted effort.

2:10:54 in 1993 to 2:08:36 in 1997. Although many other factors are involved in marathon running, it is clear that he was running at a higher percentage of his VO2 max.

How is running efficiency improved?

Researchers who carried out a long-term study of college distance runners in the United States found that over three years their average stride length decreased but their times improved. This means that their striking rate (strides per minute) must have increased. This improvement in economy is brought about by what I call 'educating the muscles'.

In physiological terms, continued training works to shorten the time between the motor impulse in the brain and the muscle contraction in the body. At the same time, a higher proportion of muscle fibres are recruited (used) at each stride, while the non-working muscles that maintain the athlete's posture become better adapted to their task so there is less wasted motion. The longer the distance run, the shorter will be the stride length: long, powerful strides may be faster, but they use much more energy because the body has to be raised more against gravity; hence a runner moving up in distance – *eg* from 10k to the marathon – must deliberately experiment with a shorter stride.

Whatever the event, an endurance athlete must constantly strive to maintain a level power output with the minimum amount of energy. And the greater the importance of technique in a given event, the more can be gained from improvements in economy. Alhough wasted effort can be seen in all sports, its dangers are most apparent in endurance sports, because there is rarely a chance to recover

Endurance 5: temperature control

Most of the energy used by our muscles is dissipated as heat. The greater your muscle bulk, the faster you produce heat, and this heat has to be lost through the skin via sweat. All long distance competitors have to be able to sweat well, and it is known that the most successful ones start sweating earlier, sweat more and have more dilute sweat. This allows them to lose heat rapidly during an event so that their core temperature does not increase. However, sweat loss poses problems of its own. You can lose as much as two litres in an hour, which adds up to about six litres for a marathon runner and far more for an Ironman triathlete. You need to find ways of replenishing that fluid – and the salt that is lost with it – before dehydration starts to affect your performance.

Endurance 6: fuel supply

When we are walking, most of the energy we use is derived from our triglyceride (fat) stores. We have huge energy reserves here: a 60kg woman with 25% body fat will have 15kg of fat, which can provide enough energy to walk over a thousand miles!

Endurance training has a direct effect on fuel supplies, boosting your muscles' stores of glycogen, triglyceride and myoglobin – an iron-containing pigment that acts as an oxygen reservoir within muscle fibres. It also increases the number of enzymes that stimulate the release of fatty acids to the muscles by as much as 200% – even 400% in some cases. This has three beneficial knock-on effects:

- Far more of these fatty acids can be used as an energy source…
- therefore carbohydrate stores can be used more slowly…
- and less lactate will be produced at any given speed.

The importance of carbo-loading

An added complication where fuel supply is concerned is that the brain can only obtain the energy it needs from glucose, which is supplied either from carbohydrate in the diet or glycogen stored in the liver. If no food is consumed, these stores decline steadily, but more steeply during exercise. It is an unfortunate coincidence that when you are running at marathon pace – say 6-minute miling – your liver and muscle glycogen supplies are likely to run out simultaneously after 2 – 2.5 hours.

When you are exercising at a low level, the glucose in your blood is being constantly topped up, partly by the glucose obtained from digestion and partly by glycogen stored in the muscles and liver. But when you are working hard, the muscles use all their stored glycogen and, once dietary glucose runs out, depletion of liver glycogen is inevitable.

For this reason, it is vital to load up with carbohydrate before embarking on prolonged exercise. Even if you take glucose drinks during exercise, the demands of that exercise will lead to a fall in your blood glucose level, which can have disastrous effects on your brain. An athlete affected in this way will start to hallucinate, then lose his sense of balance and muscular co-ordination, leading to collapse and unconsciousness.

To avoid these pitfalls, a long distance athlete must either match his pace to his fuel supply or find ways of getting more fuel into his body. If you are a marathon runner, the simplest option is just to run a little more slowly. If you reduce your pace from 16k to 12k per hour, you can continue to derive about half the energy you need from fats and there will be no danger of hitting the wall, as long as your liver glycogen levels are high and you take regular drinks.

Topping up energy supplies with drinks is a relatively easy matter for tennis or football players, who have breaks, but poses more of a problem for triathletes or ultra distance runners, who have to take in fuel while moving. Dietary methods for boosting your fuel stores are considered in more detail in Chapter 4.

You will remember that it is the increase in lactate in the blood, with the accompanying increase in acidity, which limits our steady-state running speed. At marathon speeds the use of more fatty acids allows us to 'cruise' at faster speeds than we could before training. As speed increases, however, the proportion of energy coming from fats decreases; and at 20k per hour, the speed of a world-class marathon runner, no fats are used at all, so the length of time for which maximum effort can be maintained depends on the glycogen stores.

When these stores run out, the body has to switch back to relying entirely on fats, which has a much greater oxygen cost. This is the transition marathon runners are referring to when they talk of 'hitting the wall'. Once this has happened, however high your motivation, your pace will inevitably fall off.

Endurance 7: mental strength

All the forms of endurance described above involve a certain amount of discomfort – even pain. Those with a low tolerance of pain will tend to ease their efforts and lose as a result. There is a lot of truth in the saying 'when the going gets tough, the tough get going'.

The perfect mental approach was exemplified by Emil Zatopek – the only man to win the Olympic 5,000m, 10,000m and Marathon in the same Games (Helsinki 1952). In his biography, Zatopek said: 'When I am feeling 'bad, I know that the others must be feeling worse, so I know that that is the best time to attack'. [3]

For an inexperienced athlete, much of the training process consists of learning just how much discomfort you can tolerate. With a systematic training programme, the workload gradually increases in both volume and intensity, so mental strength builds along with your physical capacity.

However, being able to rise to the challenge of hard effort is only one of the factors involved in mental strength. As an athlete, you are prey to several kinds of mental pressure – from the competition, from the spectators and also from the nature of the event itself. The history of sport is littered with examples of athletes who performed brilliantly in training and when attempting records but failed under the stress of head-to-head competition. Some performers are easily thrown by adverse weather conditions or the stress of travel, while others react positively to these upsets. In long distance events people sometimes fail simply because they are bored!

A classic example of successful mental strength training focuses on heat tolerance. The Rome Olympics of 1960 were held in August, in conditions of extreme heat that would obviously not favour athletes from Northern Europe. The 50k walk was won by Don Thompson – Britain's only gold medal-winning athlete in that Olympics. Afterwards he revealed that in the months leading up to the Games he had trained regularly in his bathroom, putting in many hours of stepping in hot, humid conditions. There is no doubt that this kind of training would have adjusted his temperature control system; but the most important thing was that he had trained himself to believe he could handle hot conditions. He had developed the specific mental strength needed to win.

How important is mental strength? In terms of actual improvement in performance, it may add up to no more than a couple of seconds at the end of an hour's racing, but that is sometimes enough to make the difference between winning and losing. Here we are really talking about lactic acid tolerance – being able to hold on during the last lap. A classic example was the Olympic 10,000m battle in 2000 between the Kenyan Paul Tergat and the Ethiopian Haile Gebreselassie, won at the last stride by the smaller but more competitive Ethiopian.

"An ability to keep going during a bad patch in a marathon and a refusal to be discouraged by bad weather conditions are factors that distinguish winners from losers"

The pressure of public expectation

Other aspects of mental strength can have an even greater influence on performance. An ability to keep going during a 'bad patch' in a marathon and a refusal to be discouraged by bad weather conditions are factors that distinguish winners from losers. Equally important is the kind of mental strength that enables an athlete to cope with the pressure of public expectation or sudden changes of climate when competing around the world.

But mental strength has its greatest impact when it is applied to training. All athletes have good days, bad days and times when a sudden disaster or personal crisis threatens to destroy their motivation. Strong and disciplined athletes distinguish themselves in such difficult times by their ability to keep going so that the momentum of the training is not lost.

Can mental strength really be improved by training? Much of our inner motivation is part of our character, sometimes even genetic. But our own experience tells us that it can be enhanced or diminished. We know that there are some times when we are absolutely determined to succeed and others when we are prepared to settle for less. In the same way, our confidence can be enhanced, not just by clear-cut realities like results but also by a variety of psychological techniques. For more on these, see Chapter 5.

Lifetime endurance

This is an area that has not been mapped, because the variables are so many, but it is as important as any of the other types of endurance in the context of a sporting career. What enables one player to survive for years and years at the top while others burn out in two or three seasons?

Genetic inheritance must be the most important factor. Someone who is 'naturally built' for a particular sport is going to have the best chance of long-term survival. Dr. J M Tanner, a medical scientist at London University, illuminated with great clarity the relationship between physical type and performance at the highest level when he wrote: '400m runners are large, long-legged, broad-shouldered and fairly heavily muscled. Long distance runners are small, short-legged, narrow-shouldered and relatively lacking in muscle'. [4]

A runner of the 400m type trying to do well in a marathon would be far more likely to break down in training because of the strain imposed on his joints by the extra weight. He would also tend to overheat much more readily because he has much more muscle bulk for a given surface area.

To take another example, the stocky athlete with well-muscled legs is well placed to cope with the stresses of football matches week in and week out because his muscles protect his joints, so twists and sprains are much less likely to occur.

Good health – and particularly a robust immune system – is obviously a major factor in lifetime endurance.

Socio-economic status Once again, the importance of this factor is best illustrated by extreme examples. Leaving aside for a moment the nutritional factors, a boxer born into poverty may have to fight far more often than a richer man but will have less access to physiotherapy or medical treatment. His chances of injury are therefore much greater. The same goes for a runner who can only train on roads and cannot afford good shoes.

Interestingly, though, social factors can often work in the opposite direction. In sports where success cannot be bought by expensive equipment or obtained through specialist training, motivation often overcomes financial disadvantage. Hungry men make the best fighters: this has been amply proven since marathon running became a money-making activity.

Applying these considerations to recreational sport, it is obvious that proper planning will prolong your career.

Table 2, below, homes in on some of the factors that can either enhance or threaten your career as an endurance athlete.

Table 2: Factors that enhance or threaten your endurance career

Career-enhancing	Career-threatening
Periodised training and competition	Haphazard scheduling of training and competition
Proper coaching	No coaching
Adequate, balanced nutrition	Unbalanced nutrition
Adequate training facilities	Poor facilities or none at all
Regular massage	No massage
Regular work routine	Irregular work
Stable emotional life	Unstable emotional life

Of course, one the biggest potential threats to your career is injury, and you need to be constantly vigilant about minimising injury risk.

At the start of any training plan, when you list such short-term objectives as 'improve aerobic fitness' or 'build leg strength', always be sure to include 'take steps to avoid injury'. This will focus your mind on building adequate recovery periods into your training, minimising the time spent training on hard surfaces and reserving your hardest training for a time when you are sufficiently prepared for it.

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Chapter 2

Age and performance

Age need not lead to loss of endurance. Older athletes may lose speed, but their experience and mental strength enables them to go on performing well for a long time. In 1987 Priscilla Welch set a British record for the marathon – 2:26:51 – when she was 42. An extreme example is the British-based Sikh runner Fauja Singh, who holds the over-90 marathon record at 5:40; another was the American Edward Weston, who in the 19th Century walked the 3,000 miles across the USA in 73 days at age 70, while in our own day we have the amazing Ed Whitlock (*see page 36*).

Nevertheless, it is inevitable that we will all slow down with age. Evolution depends on a rapid turnover of the generations and there is a built-in obsolescence in living material.

- Cells divide less frequently as they get older and eventually stop altogether;
- The total number of brain cells we have declines with age;
- Damaged muscle cells are replaced more slowly;
- Older people produce less human growth hormone, which means that damage is repaired more slowly.

As we get older, we lose muscle fibres. In the general population it is lost at the rate of around 2% and in trained athletes at an average of 0.5% per year, starting sometime between the ages of 35 and 40. The decline starts later in well-trained individuals and progresses more slowly in those who stay in training, but it is still inevitable. Fast twitch fibres are lost more rapidly than their slow twitch counterparts. And this, together with a decline of elasticity in the ligaments, means that athletes lose their speed much more rapidly than their endurance.

The good news, though, is that training raises the whole level of performance, and continued training maintains a high level.

With age, we become increasingly prone to such 'degenerative diseases' as heart disease, cancer, hypertension, diabetes and bowel diseases. But most of these are preventable to some degree, with exercise – and particularly endurance exercise – playing a significant role.

What endurance exercise does for you

1. It makes the heart stronger;
2. The arteries retain their elasticity, allowing for greater blood flow through them. With elastic arteries and a well-developed capillary system, blood pressure is kept under control;
3. It burns up fats, so reducing the risk of atherosclerosis (clogged arteries);
4. It maintains muscle strength and bone density, which normally decline with age;
5. By controlling weight, it reduces the risks associated with obesity, including diabetes;
6. By maintaining good blood flow in the brain and stimulating the release of chemicals known as endorphins, it reduces the risk of stroke and has a beneficial effect on mood;
7. It improves eyesight: the incidence of cataracts and macular degeneration is reduced among people who exercise regularly;
8. By increasing the supply of oxygen and circulating antioxidant molecules, it combats the free radical activity that can cause cancer;
9. Through sweating, harder breathing and increased bowel movement, it eliminates toxins;

10 By releasing adrenaline, it stimulates the immune system.

To take a specific example, the American marathoner Clarence del Mar enjoyed a long and successful running career and continued to run 12 miles a day for most of his life. He ran his last 15k race at age 68, two years before he died of cancer. An autopsy revealed that his heart was still very well developed and that his coronary arteries were two or three times the normal size. This is a nice piece of direct evidence that regular strenuous exercise is good for you. In a later era he might well have been able to avoid his death from cancer, but because of his exercise regime his quality of life remained good right up to his death.

In recent years, evidence has accumulated to show that regular and prolonged exercise decreases the risk of heart attacks, lowers blood pressure and cholesterol levels and so increases longevity. A number of long-term studies have proved this beyond doubt. Dr Ralph Paffenbarger Jr, studying death rates among Harvard alumni, showed conclusively that the risk of getting a heart attack decreased in line with the amount of regular exercise taken [(1)].

"Regular and prolonged exercise decreases the risk of heart attacks, lowers blood pressure and cholesterol levels and so increases longevity"

Proof of protection against heart disease

The non-exercisers in his study had a heart attack rate of 57.9 per 10,000 man-years, whereas those running 20 miles a week or the equivalent had a much lower rate of only 35.3 per 10,000. For greater distances the curve flattened out; those running 40 miles a week had only slightly more protection than those on 20mpw.

There is growing evidence that the risk of developing many forms of cancer is decreased by prolonged exercise. In 1981 the renowned epidemiologists Doll and Peto produced a paper on causes of cancer for the American Congressional Office of Technology Assessment, in which they concluded that 80-90% of all cancers could be prevented by the right exercise and diet regimes [(2)].

The consensus of medical opinion now suggests that an exercise dose of 20-30 minutes a day, three or four days a week, is enough to protect the average person against degenerative diseases. We must remember, though, that the exercise must be of sufficient intensity to raise the heart rate to threshold level – or, in other words, to make you sweat.

The pro-exercise message is now being preached so loudly in the fight against obesity that it is strange to recall how, when the London Marathon started in 1981, many doctors were still saying that exercise was dangerous for older people and that strenuous exercise was *very* dangerous.

Is it too late to start?

No, never. The marathon runner Fauja Singh had done some running as a young man, but had given up in his early 20s. After moving to Britain in his mid-80s, he took up running again after a break of about 65 years. At age 90 he ran the London Marathon in around 6:20, and the following year improved on his own record by nearly 40 minutes!

Analysing questionnaires from a survey of some 100 Master athletes, I found that among those who had taken up exercise after age 40, training brought about improvement in performance for at least three years and sometimes as long as five. Eventually, though, the slope of improvement will flatten out. Harder training may maintain performance levels for a short time, but inevitably a steady decline in performance will set in, although this in no way negates the health benefits of exercise.

The rate of improvement

Whatever age you are when you start training, you will show rapid improvement. Research into Ageing (a research trust set up by the British charity Help the Aged) studied the effects of training on a group of sedentary 75-year-olds, who boosted their muscle strength by 27% in just three months (3). A female runner I coached myself ran a 4k course in 20 minutes at age 40 before she started training; at age 48, after a year's training, she ran it in 17:00, and after a further two years' training she ran 16:20. At age 53, with three more years of regular training behind her, she ran 10k in 40 minutes – an average of four minutes per kilometre.

Can you have too much exercise?

This question is always with us. How much is enough? How much is too much? The answer is quite simple, contained within these four steps:

1. Start with a training load that you can handle, given the constraints of your daily life;
2. Working with a coach or a club, improve both the quality and the volume of your training along accepted lines (some suitable schedules are given in Chapter 5). A small (5-10%) increase in volume every two weeks is a reasonable target;
3. Keep a training diary to assess the impact of your training on your performances, taking note of fatigue, injury and illness;
4. Divide your year into periods, with specific goals for each, and assess your progress, or lack of it, at the end of each period. If you are continuing to improve, and you can find the time, there is no reason why you should not increase your training volume or introduce a new training element.

If you are seriously overtraining, the entries in your training diary will reveal the signs – continual tiredness, minor infections, bad sleeping pattern, decline in performance. The solution is to reduce the load for at least two weeks or until you feel fresher, whichever is the longer.

The best arguments for the benefits of endurance training are the national and world records set by Master athletes. When men over 40 have run sub-four minutes for the Mile, and 28:30 for 10,000m, and when women over 40 have run a marathon in 2:26, we may rest our case. The implications of these extraordinary feats is that age is no barrier to making progress.

The rate of decline

There is no doubt that our physical powers decline as we get older – but how rapid is this fall-off, and for how long can training-induced increases in fitness offset age-related decrements?

It is difficult to tell the difference between the natural decline that is due to ageing and an avoidable decline due to lack of use. Accurate statistics can only come from sport, where the effort level can be guaranteed.

Taking evidence from several sports, the consensus is that the decline in physical capacity is around 0.5% per year among those in regular training, as against 2% in the general population, after age 35 [(4)]. Oxygen intake (VO2max) declines by 9% per decade after age 25 in the general population, but athletes who remain in training can maintain it at its optimum level until their mid-30s, after which it declines at a rate of 5% per decade.

Running records from the 5k to the marathon show a straight-line decline in performance between the late 30s and age 60, at the rate of 1.5 seconds per kilometre per year, which equates roughly with the 0.5% figure given above. After 60, the rate of decline rises to something like 2.5secs/k/yr. After 70 it is less easy to be exact, but the figure is around 4secs/k/yr.

A remarkable example of slow ageing

In July 2006 the remarkable Ed Whitlock (English-born, but living in Canada) set new world bests for over-75s, with a mile in 5:41, 5k in 19:07 and 10k in 39:25. Comparing these times with world bests for the over-40 age group, we can see a decline of just 1.8 seconds per kilometre per year. Whitlock also holds the world marathon record for over-70s, with a time of 2:54. This is quite exceptional. What appears to set Whitlock apart from others is not his innate natural ability – as a younger man he was good but not outstanding – but the fact that he apparently ages more slowly than others. His uncle died at 101, so he clearly has good longevity genes – but he also runs for 1-2 hours a day!

Ageing and hormones

Human growth hormone (GH) is crucial to the processes of growth and repair in the body. It also enables athletes to cope with heavy training loads, which is why GH is used as an illegal aid to performance. As we get older, we produce less GH; but, as with the other parameters of ageing, this decline can be modified by hard training.

In research carried out at the University of Colorado, GH production in response to exercise was measured in different age groups. The bodies of young untrained men responded to the stress of exercise by boosting GH levels from 1.2 to 5.6 mg/ml. In trained young men GH levels rose to 21.9. In elderly (mid-60s) men, GH levels rose to only 2.8 in the untrained group, but to 11.3 in the trained group. Simply through training, these men had retained an ability to produce twice as much growth hormone as much younger but more sedentary men.

The same pattern has been observed in studies on testosterone levels. It has been shown that 55-65-year-old men who trained more than 40 miles a week had significantly higher testosterone levels than untrained men of a similar age.

It is clear that training has to be quite intense to influence hormone levels. This bears out what athletes and coaches know from experience: it is hard training that produces effects. Hard training means working at 85%-95% of maximum heart rate – of which more in Chapter 5.

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Chapter 3

The role of endurance in sports

This chapter looks at the requirements of a number of different sports, with a particular emphasis on the contribution of endurance to performance and the ways in which a lack of endurance may impair performance. Remember, though, that endurance is only one of many factors involved in performance, and unless it is needed to perform well training for it is a waste of time.

Almost all research on the physiology of sport and exercise has been carried out on young – usually college-based – men and women because the 18-30 age group provides most of the players, amateur as well as professional. My recommendations for mature athletes are therefore extrapolated from the evidence provided by younger people.

Do golfers need endurance training?

In golf, where a player may be hitting 140 shots in a day's play, there is a long recovery after each effort. The muscles have plenty of time to regenerate fuel and there is no oxygen demand. However, golfers may walk 8-10 miles a day when they are playing 36 holes, and endurance in this context means being able to tolerate eight hours on your feet.

The same applies to cricket: although some running is involved, the distances are short and the recoveries long. In sports such as these, it is skill that is really important, with muscular strength and flexibility also playing a role. The only endurance-related factors involved are heat-tolerance and weight control.

Older golfers, bowlers and cricketers should be encouraged to maintain their health and fitness, keep their weight down and prevent fat build-up. For these purposes, a 'weekly dose' of two hours a week of endurance training, spread over three or four days, is recommended.

The term 'intermittent work' applies to almost all the active sports, except for those demanding continuous effort – *ie* running, rowing, swimming, cycling and cross-country skiing. It applies particularly to the common team sports, including all types of football, both kinds of hockey, indoor sports like basketball, volleyball and netball, and the racquet sports – tennis, squash, badminton and fives.

Requirements of team sports

Why endurance matters in football

Clearly ball skills, agility, muscular strength and sheer speed are the most important elements of a footballer's fitness, and any endurance programme must ensure that these are not impaired. But endurance is still vital, because players need:

- to be able to play as hard at the end of the game as at the beginning;
- to be able to play another hard game only a few days later;
- to maintain their playing career for as long as 20 years.

So what type of endurance training do they need? The longest flat-out run a footballer has to make lasts about 10 seconds; but he may have to repeat this many times, with very little time for recovery, so his cardiovascular fitness needs to be good. A hard minute of sprinting up and down the pitch will result in a build-up of lactic acid that has to be eliminated quickly. The unfit player has to stop and gasp for breath, but the fit player can keep on running while simultaneously recovering.

Conventional endurance is not what is needed to withstand the knocks and twists of a hard physical game; rather this calls for all-round muscular strength, combined with flexibility and joint mobility.

Aerobic interval training v extra technical training for footballers

In a study carried out on Norwegian footballers, players in two teams were randomly assigned to either a training group or a control group, so that each team had members in both groups [3]. In addition to their regular football training and play (four 90-minute practices and one game per week), members of the training group performed aerobic interval training twice a week for eight weeks.

Each interval workout consisted of four discrete four-minute work intervals at 90-95% of maximal heart rate, with three-minute recoveries at 50-60% of max heart rate. Technical and tactical skills, strength and sprint training were emphasised in most practice sessions, and about one hour of each practice was devoted to mock football games.

While the training group members did their interval training, the players in the control group received extra technical training, including heading drills, free kicks and drills relating to receiving the ball and changing direction.

At the beginning and end of the eight-week study period, all players were tested for VO2max, lactate threshold, vertical jumping height, 40m sprint ability, maximal kicking velocity and the technical ability to kick a football through defined targets.

After eight weeks of twice-weekly interval training, the players in the training group had improved VO2max by almost 11%, from 58.1 to 64.3 ml.kg-1.min-1, but the controls had not improved at all. Similarly, lactate-threshold running speed improved by 21% and running economy by 6.7% in the training group, while controls again failed to improve at all. Clearly the players in the training group were gaining tremendous physiological benefits from just two aerobic workouts per week!

Happily, all of these physiological changes translated into some markedly improved performances on the football field. Interval-trained athletes increased the total distance covered during games by 20% (from 8,619 to 10,335m) and also doubled the number of times they sprinted during games (a sprint being defined as an all-out run lasting at least two seconds). Interval training also boosted the athletes' overall ability to play at high intensity; after eight weeks of interval work, they were able to perform at an average of 85.6% of max heart rate during their games, compared with 82.7% beforehand.

In conclusion, this very simple interval training programme produced some dramatic improvements in overall play. Boosting VO2max, lactate threshold and running economy through interval training enhanced the players' ability to cover longer running distances at higher intensities

The endurance that enables players to continue performing well at the end of a match derives from a combination of strength, flexibility and cardiovascular fitness. They also need good energy stores, heat tolerance and mental strength.

Hungarian researchers have shown that rankings in the four best teams in their top division reflected the players' average maximal oxygen uptake (VO2max) values (1). Another investigation found a significant correlation between VO2max and the distance covered by players during matches, the number of sprints per match and the frequency of participation in 'decisive situations'(2).

Some studies have also shown that footballers tend to cover lesser distances and work at lower intensities during the second half of games than during the first.

Basketball places huge demands on the cardiovascular system, suggesting that endurance training might upgrade the quality of play

Upgrading the quality of basketball play

Recent research from Australia revealed that basketball places huge demands on the cardiovascular system, suggesting that endurance training might upgrade the quality of play (4).

Maximal aerobic capacity (VO2max) was determined for each player. When the ball was in play, there was a change in movement category (for example, from medium intensity shuffling to sprinting) every two seconds, and 'very intense' activity accounted for almost 30% of court time. This translated into a heavy load on the players' cardiovascular systems, with heart rates during play averaging a high 89% of max and staying above 85% of max for at least 75% of court time. Even more impressively, heart rates were in the 95-100% of max range for 15% of court time and in the 90-95% range for 35% of the time. During free-throw shooting, heart rates recovered to around 70-75% of max.

Interestingly, blood-lactate levels were also quite high in the basketball players, with average lactate concentration at 6.8 millimoles (mM) per litre. Somewhat surprisingly, lactate levels as high as 13 mM/litre were recorded in some of the athletes, comparable to those seen in top-level sprinters after 400m races. These findings suggest that lactate-threshold improvement might benefit basketball players' performances.

As it turned out, the Australian basketball players had average VO2max readings of 61ml.kg-1.min-1, compared with 64.3 in the interval-trained football players and 58.1 in the football control group (*see panel on page 41*). This suggests not only that basketball itself boosts VO2max but also that improvements in VO2max might foster better play, just as it does in football.

What does this mean for older players?

The research described above merely proves what we already know – that skill on its own is not enough. All the components of endurance described in Chapter 1 are involved, but to different extents. In team sports such as football and basketball, arobic ftness, lactate tolerance and economy seem to be the most essential factors.

We know that VO2max declines slowly with age, and we also know that the right kind of training brings about big improvements in that area. For example, a 33-year-old player with a VO2max of 58ml/kg/min could push this figure up to the mid-60s within a year with interval training. With a rate of decline of only 0.5% per year thereafter, he would still be fitter at 40 than he was at 33.

Other aspects of endurance need not decline with age. Lactate tolerance, economy of effort and the ability to cope with heat are all capable of improving with age, as long as players work on flexibility as well as fitness

the specific demands of racquet sports

Tennis, badminton and squash make more specific demands on athletes than the sports mentioned thus far, because one arm is doing most of the work. Local muscular endurance in the arm and shoulder muscles is thus very important. Athletes still need a high level of cardiovascular fitness, a strong all-round musculature and low body fat, but the arm is all-important and avoidance of injury must come high on the list of priorities.

Endurance can be of great importance in long matches, but ‘fitness’ is a better term because it incorporates the ability to operate at a high tempo with short recovery periods, along with factors like hydration and heat tolerance. As with football and basketball, interval training for fitness makes the best use of players' time and improves endurance far more effectively than slow 'endurance runs', which impose little stress. Where possible, this training should be sport specific. In squash, where rallies can be long with very short intervals between shots, cardiovascular fitness is more important than in tennis, where the recovery periods are longer and strength and agility are more important.

Endurance requirements for different intensities

Prolonged high intensity work(1-10 minutes)

This level of work is used for:

- almost all rowing events
- middle distance running (800-3,000m)
- some track cycling and canoeing events.

The particularly type of endurance needed here is aerobic fitness. The key factor is the rate at which oxygen can be delivered by the cardiovascular system and used by the muscles; thus the emphasis must be on developing this system by increasing the supply of blood to the working muscles. This process requires long periods of aerobic training, even though the event in question may be over in less than four minutes.

Aerobic training is central to all the energetic sports because it holds the key to cardiovascular efficiency. The 400m swimmer, the kilometre cycling specialist and the serious oarsman share with the middle distance runner the need to develop both their aerobic fitness and their lactic acid tolerance to the highest degree. These are the sports where the deciding factor is just how much physical pressure and pain can be tolerated in the space of perhaps five minutes.

Since the duration of these events is short, overall fuel supplies are not a concern. However, local fuel storage can be a factor in local muscular endurance – *eg* with rowing. Training for these events must include high quality work at around race speed as well as high volume, low intensity training to improve aerobic fitness.

Training recommendations are given in Chapter 5.

Prolonged submaximal work (11-90 minutes)

This level of work is used for:

- many cycling events
- the longer track running events
- road running from 5k to 10 miles
- cross-country and fell running
- orienteering
- cross-country skiing
- short course triathlon events.

Clearly, endurance plays a major role, the crucial factors being aerobic fitness, fuel supplies and heat tolerance. Speed endurance, efficiency and lactate tolerance also have vital roles to play. In the latter stages of a 10k race or a cycling time trial, an athlete has to work harder and harder, building up more and more lactic acid, so lactic acid tolerance may well decide the outcome. However, since aerobic fitness is the most important factor, much time needs to be spent on the basic conditioning that will improve the first three factors. As competition approaches, training will be geared more closely to the event and this will involve training for the other factors. See Chapter 5 for training recommendations.

Prolonged low intensity work (over 90 minutes)

This level of work is used for:

- distance running, from the half marathon upwards
- triathlon events
- the longer cycling events.

Endurance in various different forms is the dominant factor here. Aerobic fitness is still most important because it determines the optimum work rate, but fuel supplies and heat tolerance play a more decisive role in success. Other things being equal, the athlete with the highest VO2max is likely to win; but in these long events other things are seldom equal and 'pure endurance' – which really means fuel supply – becomes crucial. See Chapter 5 for training recommendations.

In summary...

...for the majority of sports, where uninterrupted effort lasts for minutes or seconds rather than hours, 'endurance' is synonymous with 'fitness'. The better equipped you are to meet the demands of your sport – a strong arm, a well-trained heart – the easier it is to perform and the quicker your recovery will be. If you are competing in a 90-minute game, you need the endurance to last for the whole of that time; but rather than doing a lot of slow conditioning work which is unrelated to the sport, it is far better to use sport specific training, developing the fitness and the skills that the sport requires. This applies particularly to older athletes, who need to retain flexibility and mobility as well as a high level of aerobic fitness.

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Chapter 4

Nutrition and endurance

There is no food that can actually make you run faster. However, a good diet will enable you perform to the maximum level controlled by other factors, particularly oxygen supply. A poor diet, on the other hand, will lead to a fuel shortage at some crucial stage or to a slow recovery after hard training or racing.

Rest, exercise and calories

We need a certain amount of energy to maintain our physical processes all the time, even during sleep. The 'basal metabolic rate' – the amount of energy expended while at rest – is related to our body weight, specifically the weight of muscle. An average woman weighing 55kg needs 1,300kcals and a 65kg man needs 1,600kcals just to stay alive. The higher your ratio of fat-to-muscle, the lower your energy needs. Additional to this basic requirement is the energy you need for your daily activities, which brings the total requirements up to about 2,400kcals and 2,700kcals per day respectively.

Additional exercise can increase your energy expenditure very rapidly. For example, hard exercise like running or rowing will burn up 8-10 kcals per minute. Moreover, the more intense the exercise, the more it stimulates the metabolism and suppresses the appetite. On the face of it, three hours of golf at 3kcals per minute burns up as much energy as an hour of

'Ideally your body weight and waist measurement should be the same at 41 and 61 as they were at 21'

hard exercise at 9kcals a minute; but the latter will be much more effective for controlling weight.

Surveys of the general population show that the overall trend is for people to get weaker, fatter and heavier with age. This process is accompanied by an increase in blood pressure, which raises your risk of cardiovascular disease. It has been argued that basal metabolic rate automatically declines with age; however, this does not apply to active people. Studies on primitive hunter-gatherer tribes found no increase in body weight or blood pressure with increasing age, and this was attributed to their high levels of exercise. In the modern world, too, there is good evidence that regular activity increases the basal metabolic rate.

Why weight need not increase with age

First, it is not inevitable that weight will increase with age. Figures quoted for 'ideal' or 'average' weights are often taken from life insurance tables, which give averages for Western populations. Ideally, your body weight and waist measurement should be the same at 41 and 61 as they were at 21.

As we know, 'endurance' is often a matter of aerobic fitness, measured in mls of oxygen taken in per kilogram of body weight. Hence, the more your body weight increases, the more your aerobic fitness will decline.

In a study comparing men who took regular endurance exercise with those who did not take part in any regular activity, it was clear that active older adults had a higher resting energy expenditure than sedentary ones [1]. A number of other researchers have found that involvement in aerobic exercise offsets the age-related decline in metabolic rate. Weight training has also been promoted as a way of maintaining resting energy expenditure.

If you still find you need to cut down on what you eat to maintain your desired weight, you will need to give more thought to the quality of your diet. If you're an endurance cyclist burning up 5,000kcals a day, you can get away with eating some foods that provide calories without much nutrition – *eg* those rich in refined sugars – because you'll still have room for foods that contain the required amounts of vitamins and minerals. However, if your intake dips below 2,000kcals a day, you need to make sure that everything you eat is 'nutrient-rich'.

Another reason for paying attention to the quality of your food as you get older is that age-related changes in the gut make you less efficient at absorbing nutrients from food.

Essential nutrients

It is clear, then, that we need a better diet as we get older. The emphasis should be on foods that have a high nutrient content, not just ‘empty calories’. This means increasing your intake of fresh fruit and vegetables, dairy products, whole-wheat bread and high-protein food.

Foods tend to be richer in vitamins and minerals the closer they are to their natural state. This is particularly true of fruit, vegetables and cereal-derived foods. For example, the refining process that strips away the outer husk of wheat grain to make white flour also strips away significant amounts of B vitamins (which play a crucial part in converting carbohydrates to energy), vitamin E, iron and zinc. Thus it is important to choose whole foods when you can.

Remember, too, that vegetables fare best with minimal cooking, since prolonged soaking and boiling lets vitamins (B1 and C in particular) seep away. The current recommendation from the UK Department of Health, that a good diet should contain five portions of fresh fruit or vegetables per day, applies even more forcefully as you get older.

It is important to distinguish between the basic foods we need (carbohydrate, fats and proteins) and the ancillary nutrients needed to keep us healthy and functioning at 100% efficiency – *ie* vitamins and the minerals. Articles on diet and nutrition often stress the importance of the latter, ignoring the need for regular supplies of the basic ingredients.

Carbohydrate for energy

The more you exercise, the more carbohydrate you need in your diet. For those training hard, the recommendation is that 60% of the day's energy requirements should be met by carbohydrate. An hour's hard running can use up as much as 1000kcals – around 40% of a day's normal energy expenditure. When I was running 50 miles a day across the USA, I was using an estimated 5,000 extra kcals per day; in the Tour de France stages, as much as 8,000kcals can be expended by a single cyclist in a day. If you lack the fuel, you cannot go on performing at the same level; and this applies equally to young and older athletes.

It is important for athletes to refuel with carbohydrate either during the exercise or as soon as possible afterwards. During exercise, the enzymes that promote the breakdown of glycogen to glucose are working at their maximum capacity; and they will catalyze the opposite process – glucose to glycogen – as soon as the exercise stops and the blood glucose concentration rises. It is for this reason that athletes are encouraged to take in carbohydrate immediately after exercise. Common practice is to have a high-carb drink immediately afterwards, then eat a meal within an hour.

Why muscles prefer glucose

The preferred fuel for exercising muscles is glucose. A delicate control system monitors the glucose levels in your blood, maintaining a concentration of 0.1%. Whenever the concentration of blood glucose rises, as it does after a meal, the body produces insulin, which converts the excess glucose to glycogen to be stored in either the liver or the muscles.

The liver contains about 100g of glycogen, but this is not normally called on by the muscles. Rather, it is a 'reserve tank', used to supply tissues that rely solely on glucose, notably the brain. If blood glucose concentration drops, the brain soon feels the effects, as marathon runners will be only too well aware!

Our muscles can store around 600g of glycogen; since the energy content of glycogen is just under 4kcals per gram, this yields an energy supply of about 2,200 kcals. A top-class marathon runner, running at 2hrs 10 mins pace, slightly faster than five minutes per mile, will consume 1,300kcals per hour, so his glycogen supply will run out before the finish unless he can find some way of getting more fuel on board, either by drinking during the event or by dietary manipulation beforehand.

Sugars, starches and the glycaemic Index

Not all carbohydrates are alike: some contain a lot of glucose, which is released into the blood very quickly, while others contain a lot of starch, which has to be digested and broken down into single molecules of glucose before being absorbed. Pure glucose is said to have a 'glycaemic index' (GI) of 100, while a food containing mainly starch, such as lentils, has a much lower GI of 28. Fruits contain fructose, which has to be converted into glucose before it is used in respiration, so fruits tend to have a low GI (*see Table 3, overleaf*). Table sugar, or sucrose, is a 12-carbon compound of glucose and fructose; thus it has a lower GI than pure glucose but gives a more prolonged energy boost.

Simple sugars provide an instant energy boost, which is why climbers pack supplies of Kendal Mint Cake. However, too high a glucose intake will give rise to the 'insulin effect', whereby glucose is removed from the blood and stored as glycogen. For those carrying out heavy training over long periods, the ideal solution is to take in a mixture of carbohydrates, some providing rapidly-available energy and others releasing it more slowly. The latter group are the starches or polysaccharides – long chains of sugar molecules which are broken down gradually.

In simple terms, an athlete doing high volume training can pack away as much carbohydrate as he can stomach. The same does not apply, however, to the 'urban sportsman', who is putting in, say, five or six hours training per week and has to balance his intake and output as well as the constraints of work and travel. For such people it is important to eat the right foods at the right time – and this is where the glycaemic index comes in.

Other factors also slow down the release of glucose. Substances that contain a lot of fibre, such as oatmeal or fat, take longer to digest. Thus they release glucose more slowly and have a lower GI.

Table 3 Glycaemic index of carbohydrate sources

Food Material	GI
Banana (ripe)	58
Mango	56
Sweet corn	55
Special K	54
Potato crisps	54
Chocolate	49
Peas	48
Grapes	48
Baked beans (tinned)	46
Porridge	46
All Bran	43
Spaghetti	43
Peach (raw)	42
Tomato juice	38
Apple	37
Milk (skimmed)	32
Apricot (dried)	30
Banana (unripe)	30
Peanut butter	29
Lentils	28
Milk (full fat)	27
Soya beans	20
Yoghurt (unsweetened)	1

Food and endurance

The greater your training volume, the more food you need to eat, and the more important it is to stick to low GI foods, except at the end of the day. It is a good idea to eat or drink sugary high GI foods immediately after a hard effort, but to ensure a constant energy release over many hours it is best to base your meals on low-GI foods.

Several studies on athletes in long low intensity events, mainly cycling, have shown that, given equal amounts of carbohydrate in their meals, those eating low GI foods have been able to maintain their work rate for much longer periods than those eating high GI foods.

Carbo-loading for marathon endurance

Because the marathon distance is a little longer than the human body can comfortably handle, numerous ways have been tried of boosting the body's natural reserves. The 'carbo-loading diet' was based on trials carried out in Sweden, when glycogen reserves were depleted by hard training and kept artificially low for several days. In the last three days before the race, the runners then gorged themselves on carbohydrate, resulting in a 'supercompensation' effect, which boosted muscle glycogen stores by as much as 100% for a short time.

Subsequent work by the American physiologist David Costill has shown that it is not essential to deplete reserves before the carbo-loading phase. This applies particularly to high-mileage runners, who are regularly running 15 or 20 miles a day. For those on lower mileages, there is evidence that some depletion beforehand will enhance the subsequent loading.

Much depends on the level of training. Well-trained athletes can raise their glycogen levels to much higher levels than their untrained counterparts *(see Table 4, overleaf)*. To load fully, the amount of carbohydrate taken in the last few days should make up around 60-70% of your total intake, if you can do this without upsetting your digestive system.

The units in the table refer to grams of glycogen per kg of muscle or liver tissue. Since the liver weighs only about 1kg, the total glycogen store does not exceed 100g, but a lean athlete will have 15-20kg of muscle, so the total store in muscle, when properly loaded, might be as much as 700g. A smaller person will have less muscle, and so less glycogen, but his or her energy consumption will be proportionately less.

Athletes are advised to follow these tips:

- If you are susceptible to blood sugar swings (*ie* you often experience an energy dip 30-60 minutes after eating a carbohydrate-rich meal or snack), stick to low GI carbs for three hours before training, whatever the duration/ intensity of your event, as these are less likely to disturb your blood sugar and adversely affect your performance;
- If weight control is a priority, avoid high GI pre-exercise snacks, which reduce the proportion of energy derived from fat burning during subsequent training;
- Away from training, try to emphasise low GI carbs in your diet, as these are less likely than high GI carbs to over-stimulate your insulin system;

- The GI of carbohydrates are reduced by fat consumed with your meal. For optimum glycogen replenishment, consume your moderate/high-GI carbs with only small amounts of fatty foods.

Table 4: Muscle and liver glycogen levels

(grams of glycogen per kg of muscle/liver)

Untrained subjects			Trained subjects		
Diet	45%CHO	70%CHO	45%CHO	70%CHO	Fasting
In muscle	14	18	21	36	21
In liver	54	70	70	90	10

To explain the figures in the table, '45% CHO' refers to the normal amount of carbohydrate in the diet and '70% CHO' to the amount 'loaded' in the three days before a marathon. The 'fasting' column shows the effect on the trained subjects of fasting for 24 hours.

What you can see is that the untrained subjects increased their glycogen stores on a high carbohydrate diet, but not by nearly as much as the trained athletes. The high figure of 36g/kg was obtained because the athletes were resting, or doing very light training, while they were on their loading phase.

You can also see that liver glycogen stores fall very rapidly when no food is being taken in. The muscles can switch over to using their fat stores, but the brain has to have glucose, so the liver glycogen dwindles to almost nothing.

The lesson to learn is: always eat breakfast on the morning of your event; that way you will start with a fully-loaded liver and muscles. In terms of performance, an untrained person, with 12kg of muscle, on a normal diet, would have about 168g of glycogen in his muscles and a further 54g in the liver. A trained person of the same weight with, say, 15kg of muscle, and using carbo-loading, would have 540g in the muscles and 90g in the liver.

Fats as a glucose substitute

When we are moving at a slower pace, or enjoying a break between bouts of energy, fat metabolism can replace glucose metabolism

Fats form an essential part of our diet. Many of our vitamins are fat-soluble, and for those engaged in long term endurance events lasting more than a few hours fats provide most of the energy. In medium term endurance events, lasting from half an hour to, say, six hours, they offer an alternative to carbohydrates as an energy source. Fats are broken down into fatty acids, which are then introduced into the respiration cycle in the muscle fibres.

Humans store fat under their skin and around their organs. Percentage body fat is often used as a measure of fitness, and the norm for people in serious training is around 10% for men and 12.5% for women. Figures of 8% (men) and 10% (women) are not uncommon, but body fat in the region of 5-6% would be regarded as dangerously low.

In sedentary people, percentage body fat is often as high as 20% and 25% for men and women respectively. In evolutionary terms, fat played an important role in keeping people warm in cold weather and providing them with fuel reserves during hard times; but in the modern developed world, it has no value and is merely an impediment.

When fat can be useful

Fatty tissue is dead weight, since it contributes nothing to movement and takes up some of the blood that could be used by the muscles. Moreover, the heavier you are the greater the energy cost for every metre of movement. A man weighing 80kg may be carrying 20kg of fat, amounting to 180,000kcals. This reserve would provide enough energy for him to live on for about 74 days!

However, fats can be useful. Our glycogen reserves are limited, and when we are moving at a slower pace, or enjoying a break between bouts of energy, fat metabolism can replace glucose metabolism. Nowhere is this seen more clearly than during a marathon, when regular walking breaks allow the blood sugar level to rise a little, preventing complete exhaustion. The problem for athletes is that fatty acid metabolism requires about 10% more oxygen than glucose metabolism to produce the same amount of energy, and thus the more you rely on fats for your fuel, the slower you will go.

Most of us, though, use some fat in our running, and efficient fatty acid metabolism is part of the training of the long distance performer. Just doing long runs will enable you to burn up more fat and to become more efficient in doing so. Running before breakfast is also a good way to burn fat. Older runners in particular need to keep an eye on their body fat percentage, because without proper training muscle mass decreases and fat percentage rises.

Proteins for bodily repair

Proteins are the essential building blocks of our cells. Muscle fibres are made of proteins; the enzymes we rely on for carrying out all our bodily reactions are proteins, and so is the haemoglobin that carries oxygen in our bloodstream to all parts of the body. Children need proteins for growth, but in adults they are essential for repair and so are particularly important in sport, which involves a rapid breakdown of tissues.

The UK Department of Health recommends a protein intake of 1.2g per kg of body weight per day for young, active males, and 1.0g/kg for females. This means an intake of 60-80g of pure protein per day. There is no evidence that a higher protein intake will improve performance: in fact, it could have a detrimental effect because excess protein leads to excessive urea production and more frequent urination. Also, an athlete eating a protein-rich meal will often be eating a lot of fat as well and will thus not take in enough carbohydrate. In terms of of calorie intake, protein should make up 15-20% of the total.

Proteins differ enormously in their structure and function. Each type of protein molecule is composed of hundreds of amino acids. There are 20 different amino acids in human protein, of which only half can be synthesised by the body, so the remainder – the 'essential' amino acids – must be taken as part of your diet.

Proteins from animal sources – meat, fish, eggs and milk –

contain all the essential amino acids; but proteins from plant sources don't, which is why vegetarian athletes need to obtain their protein from a wide range of food substances.

The essential amino acids are:

- histidine
- isoleucine
- leucine
- lysine
- methionine
- phenylalanine
- threonine
- tryptophan
- valine.

Table 5: Composition (per 100g) of major foods

Food	Energy (kcals)	Carbohydrate (g)	Fat (g)	Protein (g)
Baked beans	64	10.3	0.5	5.1
Bread(w/meal)	218	41.8	2.7	8.8
Bacon, raw	415	0	40.5	14.4
Butter	724	0	82.0	0.4
Eggs	146	0	10.9	12.3
Low fat spread	358	0	40.7	0
Cornflakes	376	85.1	1.6	8.6
Cheese (cheddar)	400	0	33.5	26.0
Chicken, raw	227	0	17.7	17.6
Fish, white	76	0	0.7	17.4
Lentils, dry	308	53.2	1.0	23.8
Milk, whole	65	4.7	3.8	3.3
Milk, skimmed	34	4.7	0.3	3.3
Potatoes, raw	88	20.8	0	2.1
Rice, dry	366	86.8	1.0	6.5
Spaghetti, dry	384	84.0	1.0	13.6
Pork sausage	362	9.5	32.1	10.6
Steak, raw	175	0	20,2	10.6

You can see from Table 5 on the previous page that most high protein foods are also high in fat; and a useful way of looking at these figures is to compare the proportions of protein and fat in foods. From this perspective, you can see that bread, cornflakes, rice, potatoes, beans and pasta score well since they have very little fat. Among the high protein foods, fish, eggs and lentils have a lower percentage of fat than, say, cheese or chicken.

The need for fluid replacement

The need for adequate hydration has been emphasised so much that the pendulum has swung too far in the other direction. It is certainly true that dehydration impairs performance and that serious dehydration can lead to heat exhaustion. The sensation of thirst declines with age, which means that in certain situations – with air travel, for example – you may become partially dehydrated without realising it. However, if you are well hydrated when you start exercise, the loss of fluid is not going to affect your performance in the first hour.

When we are exercising hard, we lose fluid through sweat at the rate of 1-2 litres per hour, so an average person, sweating freely, will lose at most 3% of body weight – a loss which evolution has designed us to handle. At the start of a marathon, an athlete who has reduced his training and increased his carbohydrate intake will have extra water stored with his glycogen, so that his starting weight will be 1-2kg above normal. As the race goes on, he will become lighter and actually able to run faster. It is only in the last few miles that there is a risk of dehydration and overheating, and this can be avoided by judicious drinking every 15-20 minutes, beginning one hour after the start.

It is not necessary to drink during events lasting an hour or less; and it is important to realise that drinking too much water without any electrolytes has the effect of flushing salts out of your body, leading to a dangerous condition called hyponatraemia. If you are taking drinks over a long period of time – *ie* for two hours or more – they should contain the electrolytes (salts) which you lose when sweating. Isotonic sports drinks are a good choice in this respect.

Vitamins and minerals

The most important vitamins and minerals are listed in Table 6 on page 63, along with their functions and sources. As a rule, it is always better to obtain these 'micronutrients' from natural sources rather than synthetic 'multivitamin' pills, since many of these are simply not absorbed by the gut (*see 'the balanced diet' on page 64*).

Diet and the immune system

Distance runners know all too well that you tend to pick up infections when you are really tired. Research has shown that after a marathon the risk of getting a throat infection is six times higher than normal. That's because hard exercise destroys the white blood cells that normally protect us.

However, It has also been observed that really good performers are seldom ill. Why is this? Are they able to handle a lot of training because they have naturally strong immune systems? Or does their hard training make them resistant to infection? And can the right diet strengthen the immune system? The answer to both of the first two questions is a qualified 'yes'. Some studies have shown better-than-average natural immunity in elite athletes and cyclists, while studies on the effects of training on the immune system have shown beneficial effects in some cases but not in others. This was probably because the link with diet was not fully understood.

An experiment carried out in Denmark looked at the effects of training and diet on 'natural killer' (NK) cells – the white blood cells that actively destroy tumour cells and certain viruses [(2)]. The subjects – all young men – were divided into two groups, one assigned to a high carbohydrate diet and the other to a high fat diet. In each group, half were also assigned to a regular training regime for seven weeks, while the others did not train. In the trained group, there was an increase in the concentrations of some of the NK cells, but overall the level of white cells remained unchanged. Where significant differences did show up was between the two dietary regimes. In the high fat group, the level of NK activity fell, while in the high carbohydrate group it rose.

The implications is clear: a combination of regular training and a high carbohydrate diet improves your immune system.

Free radicals and antioxidants

Free radicals are highly active compounds that attack cells, membranes and even DNA. They help to cause the degenerative diseases that affect us in later life.

Antioxidant nutrients, found mainly in fruit and vegetables, 'lock up' these free radicals and prevent them from causing damage. Vitamins E, A and C seem particularly important in this respect. Vitamin E has been shown to help combat the effects of exercise-induced oxidative stress (working hard and getting out of breath), which increases free radical production, while vitamin C protects against heart disease. Of the minerals, zinc and selenium are the most important. The older you get, the more important it is to have these compounds in your regular diet.

Some good examples of foods containing antioxidants are:
- tomatoes
- blackberries
- oranges, grapefruit and other citrus fruits
- onions
- apples.

Zinc
Zinc is an important mineral, activating numerous enzyme systems in the body, including those involved in antioxidant action. It is found mainly in sea food, red meat, milk, eggs and rice.

Calcium
A deficiency of calcium in the diet is linked with a number of diseases in older adults, including osteoporosis (thinning of the bones), cancer of the colon and hypertension. The osteoporosis risk is particularly high for postmenopausal women, although fitness, and particularly muscular strength and endurance, has a part to play in preventing it [3].

Because we absorb minerals more slowly with age, we need to pay more attention to the calcium content of foods. The best sources are milk products: skimmed or semi-skimmed milk are fine because of their relatively high calcium content, and so are yoghurts, low fat cheeses, tofu, and green leafy vegetables.

Vital to the uptake of calcium is vitamin D, which we can synthesise ourselves as long as our skins are exposed to sufficient sunshine. Even in the UK, people who exercise outdoors will produce enough vitamin D for most of the year, but it is a good idea to increase the amount in your diet (by eating more fruit and vegetables) in the winter months, from November to March.

Iron

This mineral is absolutely crucial to top class performance, being the essential ingredient of haemoglobin, which forms about one third of the mass of each red blood cell. These cells are manufactured on a continual basis in the bone marrow. Iron is also an essential ingredient of the enzyme responsible for making DNA.

‘It is a good idea to increase the amount of vitamin D in your diet in the winter months, from November to March’

Research has shown that many endurance athletes have low iron stores[4]. The problem is that both high mileage and high intensity training have the effect of destroying red blood cells, leading to increased stress on the bone marrow, and in some cases to actual loss of blood in the urine. When athletes are training hard, the volume of their blood plasma – the liquid part of the blood – increases. This may result in a temporary drop in the proportion of haemoglobin in the blood (normally in the range of 14-17g per 100ml). Increased bone marrow activity restores the level – but only by depleting iron reserves. If the breakdown of red blood cells continues, anaemia is the inevitable result.

Key to this are blood levels of ferritin, the body’s iron storage molecule. The normal range is 50-150mg/L, but in studies carried out by the American physiologist David Martin 13 out of 15 marathon runners were found to have ferritin levels below this range [4]; and in four cases they were below 20mg/L, suggesting that the athletes’ bone marrow iron stores were down to zero.

Failure to maintain iron stores is a frequent cause of poor performance and interrupted training. Anaemia caused by iron deficiency is also quite common in older people, caused by low protein diet, poor iron uptake or blood loss.

Since absorption of minerals tends to decline with age, maintaining a high iron uptake is vital to older athletes. The primary sources of dietary iron are liver and red meat; others include leafy vegetables, egg yolks, baked or boiled potatoes and dried fruit (*see Table 6, opposite*). Note that iron uptake is greatly impeded by drinking tea with meals. To ensure proper uptake of iron, you need plenty of vitamin C, preferably in the form of fresh fruit and vegetables

Fibre

Lack of fibre in the diet leads to constipation, and this can cause bowel problems, including cancer. However, active people suffer less from constipation than sedentary types, and as long as you are eating plenty of fruit and vegetables, it is quite unnecessary to act extra fibre to your diet.

When alcohol is good for you

It is a good idea for people over 40 to drink alcohol in moderate amounts because it protects the cardiovascular system by thinning the blood, making clotting less likely. In addition, it helps to prevent gallstones and prostate cancer and there is even some evidence that it helps brain function – or, at least, limits deterioration.

But the operative word here is 'moderate'. The recommended limits are 2-3 units a day for women and 3-4 units for men, with a maximum of 18-24 units per week. A unit is made up of half a pint of beer or a small (125ml) glass of wine, both of average strength. A large glass of wine with 14% alcohol is nearer to 2.5 units. It makes no difference whether the alcohol is taken as wine, beer or spirits.

The point about alcohol is that it is metabolised at the rate of about one unit per hour, so one or two drinks the night before a performance will not affect you, providing you drink enough water afterwards to remain fully hydrated. Indeed, the relaxing and social effects of alcohol may even help you to perform better. On the downside is the fact that alcohol provides 'empty calories', with very little in the way of nutrients. One unit of alcohol provides about 90kcals, so even a modest consumption of 20 units a week adds up to 1,800kcals, which you will need to work off if you are to avoid putting on weight.

Table 6: Dietary sources of key micronutrients

Vitamins

Vitamin	Needed for	Sources
A	Eyesight, cell division	Oily fish, butter, cheese, carrots, apricots
B1 (thiamin)	Carbohydrate metabolism	Bread, cereals, potatoes, pork, liver, nuts
B2 (riboflavin)	Supporting other B group vitamins	Milk, eggs, meat, breakfast cereals
B6	Protein metabolism	White meat, fish, nuts eggs, soya beans, oats
B12	Nerve cells, folic acid metabolism	Meat and fish, also made in the gut
Folic acid C	Cell division, DNA and protein formation	Leafy veg, liver, whole grain foods, pulses, nuts
D	Calcium absorption, bones, teeth	Fruit and veg, esp citrus fruit, kiwi, potatoes
E	Vital antioxidant	Veg oils, wheat germ, nuts, seeds, margarine

Minerals

Mineral	Needed for	Sources
Calcium	Bones, teeth, blood clotting, muscles	Dairy products, green veg
Sodium	Fluid balance, muscle function	Salt
Potassium	Heart beat, fluid balance	Bananas, fruit, seeds, nuts, pulses
Zinc	Immune system, healing, metabolism	Sea food, red meat, milk, eggs, rice
Iron	Blood, oxygen transport	Offal, meat, egg yolk, green leafy veg
Selenium	Antioxidant properties	Brazil nuts, offal, fish, avocados, lentils

Diet and joint problems

Constant wear and tear often leads to problems in the lower limb joints, whether you are active or sedentary. These problems may be caused by thinning of the cartilage layers that protect the bones, by tendon or muscular problems, or by inflammation, as in arthritis. Some of these conditions respond to treatment with dietary supplements, and the two most favoured by Master athletes are glucosamine and chondroitin sulphate.

For rheumatoid arthritis, the most effective dietary remedy appears to be fish oil. The oil from certain fish, including mackerel, salmon, tuna, sardines, pilchards and herrings, contains the omega-3 fatty acids that are able to damp down the body's inflammation response and bring relief from arthritic pain. Other sources of these fatty acids include walnuts, pumpkin seeds, flax and flax-seed oil, and wheat germ.

Bioflavonoids, naturally occurring compounds found mainly in fruit and vegetables, appear to possess anti-inflammatory properties in addition to their antioxidant effects. Animal studies on two such compounds, rutin and quercetin, have demonstrated significant anti-inflammatory effects in both acute and chronic inflammation.

The balanced diet

On questions of diet, it is easy to become blinded by science. And it is worth bearing in mind that Kenyan and Ethiopian athletes perform very well on small budgets, without the aid of nutritional science.

A diet containing bread and butter, cereals and fruit, carbohydrates, meat, fish and eggs will cover most of the bases, but to make sure you are covering all your body's needs, a few rules will help.

1. Eat at least five portions a day of fruit and green leafy vegetables. You can achieve this by having fruit juice for breakfast and fruit with your cereal, having a salad or green vegetable at lunch and dinner, and eating fresh fruit for your second course or as a snack. In general, if you eat an apple, an orange and a tomato every day, you won't go far wrong.

2. Base each meal on a carbohydrate, such as bread, rice or pasta, so that your calorie intake is balanced throughout the day.
3. Eat the following at least once a day, preferably more:
   - milk and dairy products
   - a protein source such as fish, meat or eggs
   - nuts or seeds in some form, *eg* wholegrain bread.
4. Restrict fats to no more than 25% of your total calorie intake.
5. Drink plenty of water.

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Chapter 5

Training for endurance

Whatever your chosen sport, you must start by analysing your needs. What are your strengths and weaknesses? In what areas can you still expect to improve? What training is needed to offset the effects of increasing age?

As explained in Chapter 1, the seven components of endurance are:

- lactate tolerance
- specific muscular endurance
- aerobic fitness
- efficiency
- fuel supply
- temperature control
- mental strength.

How fit are you?

The ultimate test, of course, is performance, but you can make your training more purposeful if you can carry out some objective tests on a regular basis. Here are some you could try.

Multi-stage fitness test (bleep test)

This estimates aerobic power, or VO2max, in ml/kg/min. It is very good for games players as it is specific to the nature of their sport, but not suitable for rowers, swimmers or cyclists, who will achieve higher scores on specific tests. Also, endurance athletes may have trouble with the short turns involved. Scoring works as follows:

- Level 8 = 40 ml/kg/min
- Level 10 = 47 ml/kg/min
- Level 12 = 54 ml/kg/min
- Level 14 = 61 ml/kg/min
- Level 16 = 68 ml/kg/min
- Level 18 = 75 ml/kg/min

Cooper test

This alternative to the bleep test as a test for aerobic fitness is very simple, being the maximum distance you can run in 12 minutes. VO2max is estimated, according to this mathematical formula: 22.351 x k - 11.288. Table 7 gives ratings for athletes over 40.

Table 7: Cooper test ratings for older athletes

Age	Excellent (m)	Above average (m)	Average (m)	Below average (m)	Poor (m)
Males 40-49	>2,500	2,100-2,500	1,700-2,099	1,400-1,699	<1,400
Females 40-49	>2,300	1,900-2,300	1,500-1,899	1,200-1,499	<1,200
Males >50	>2,400	2,000-2,400	1,600-1,999	1,300-1,599	<1,300
Females >50	>2,200	1,700-2,200	1,400-1,699	1,100-1,399	<1,100

Remember, though, that these estimates are for distances run in a trial situation, not a race.

300-yard shuttle

This is a test of intermediate anaerobic power, *ie* lactate tolerance. It is performed as a shuttle run over 25 yards (300 = 12 x 25). This is a good test for games players as the shuttle format makes it sport specific. It is especially good for football, rugby, hockey, basketball and squash.

Planning your training

It is generally agreed these days that competing all year round inhibits progress and that 'periodisation' provides a better pattern of training. With periodisation, the year is divided into phases: basic conditioning, pre-competition, competition, and resting. Some sports may have two main competitive seasons.

The most successful performers are those who plan ahead, and the questions they and their coaches need to address together are:

1. How long is the competitive season?
2. What are the peak events?
3. How much time should be allocated to conditioning and how much to pre-competition?
4. If the competitive season is very long, should there be a return to conditioning before building up to a second peak at the end of the season?

At all stages, training should offer variety, challenge and enjoyment, irrespective of the long term goal. Boredom is the enemy, particularly for older runners who have been through many training cycles. The sense of progression in each phase gives you confidence and prepares you to move up in the next phase.

The conditioning phase

In this phase you need to build all the qualities that will be needed in the later phases. First you must decide how much basic conditioning is needed to meet the demands of the approaching season. The duration and the content of this period must relate to the more intense training to follow. How much time is available? And is it worth spending time on prolonged endurance work that is not directly related to the requirements of your event?

There are two areas of improvement that need to develop

'Masters probably need to spend less time on conditioning than younger athletes because they are already attuned to the demands of their sport'

in parallel – the ability of your muscles to process oxygen and the ability of your cardiovascular system to deliver oxygen to the muscles. Long slow training will develop aerobic fitness because it encourages the development of the capillary blood vessels in between the muscle fibres, and this accounts for the high volume training of top class runners, cyclists and triathletes. The intensity of this training is very low, with the heart rate staying below 75% of maximum (90-130 beats per minute).

Slow paced training lasting 1-3 hours is important for improving heat tolerance, fuel storage and fuel management. It will form an essential part of the conditioning process, as can be seen in some of the sample schedules given later in this chapter, but it is not the complete answer.

The basic conditioning needed for any sport should include muscular strength, flexibility and mobility, but our brief here is endurance training. If you consider the maximum demands that are going to be imposed on you in the season ahead, you should be able to work out how much training is needed.

In elite-level marathon running, where athletes have to run hard for two-and-a-quarter hours, I normally advise building up to running for three hours and exceeding the race distance. The daily training probably adds up to 90 minutes or two hours on most days.

Non-stop training for footballers

Extrapolating from this, a footballer preparing for a 90-minute game should be able to train for up to two hours non-stop at maximum, and his daily training should add up to more than an hour.

For sports requiring ball skills, only a little time need be spent on pure endurance training; once players have acquired the necessary endurance, much of their training will consist of event specific work. So for hockey, for example, repeated drills of 'sprint, collect, dribble, pass' might last for 30 minutes, forming the core of a 90-minute workout.

Masters probably need to spend less time on conditioning than younger athletes because they are already attuned to the demands of their sport. Unless you have put on a lot of weight, your body needs only a brief 'reminder' lasting a week-or-so before moving into more specific training. However, you will need to monitor yourself carefully for signs of stiffness or lack of flexibility after training.

FAQs on endurance

How much of weekly training should be spent on endurance?
To some extent, every session does something for endurance, but if the training session is less than half the volume of the competition it cannot be regarded as an endurance session in itself.

In the initial conditioning phase, most of the training will be solely for endurance, but as soon as you reach the target volume of training, you should switch to event specific training sessions, first once a week, moving up to three or four times a week.

In the peak training period for an endurance athlete, working on a three-day cycle of 'easy-moderate-hard, easy-moderate-hard, long', only one day in seven is given over to endurance. In another sense, however, every day is an endurance day, because the athlete is training two or three times a day. As competition approaches, the pure endurance session will be relegated to once every two or three weeks. The day after competition will often be a slow running day, but this is more for recuperation than for training and will not generally be long enough or hard enough to qualify as an endurance session.

For the 'urban sportsman', competing most weekends, there is a risk that 'detraining' might occur. My recommendation here is to incorporate one endurance session into your schedule at least every two weeks. This should be a continuous effort lasting at least an hour for ball players, 1.5-2 hours for runners and maybe four hours for cyclists. For marathon runners, I would recommend 2-3 hours of continuous running.

Is it better to run for two hours or do two one-hour runs?
If you are training for a marathon, you need two-hour runs occasionally, not just for endurance but for learning to run economically at your race speed.

If you are training for events involving less than an hour of running, your main needs are for oxygen intake and speed endurance and you are better off doing specific sessions, involving fast running, which will benefit those aspects of fitness.

In a 60-minute session, you can spend 15 minutes on warm-up and five minutes on warm-down, leaving 40 minutes for hard training; this is enough time for 16 x 400m, with 60secs recovery, or 5 x 1 mile (in sub-6 minutes, with a 2-3mins recovery). Almost as effective would be a 'threshold 'session, where your warm-up is followed by 2 x 15-20mins at your half marathon pace, with a 2mins jog between the two fast runs. Older athletes, in particular, will benefit more from a quality session than a slow plod.

Can you have too much endurance training?

In absolute terms, the human body has a tremendous capacity for absorbing training. It was in the 1960s that the New Zealand coach Arthur Lydiard established the 'hundred miles a week' principle for aerobic conditioning, and this is still accepted by many coaches as the maximum that can be sustained for long periods.

The eminent American physiologist David Costill believes that 70 miles a week is the maximum that can be maintained consistently, and that exceeding this limit frequently is more likely to harm than benefit you. However, successful marathon runners in Kenya and Mexico commonly clock up 120-150 miles (180 -240k) per week, in addition to gym work, for two or three months before a race. Orienteers in Scandinavia spend as much as 30 hours a week in training, while full-time cyclists and triathletes also put in 5-6 hours a day for 5-6 days a week.

Most running coaches would agree that 200 miles (320k) a week is too much running. I myself covered 1,000 miles (1,600k) in three weeks while running across the United States in 1969, but this is not recommended as a form of training! In swimming, where there are no problems of impact stress, training loads can amount to as much as six miles(10k) a day or 30 miles (50k) a week.

In terms of single training sessions, marathon runners will go up to 30 miles (50k) in a single run and cyclists will pedal

Long distance preparation

Running guru Professor Tim Noakes has firm views on preparation for long distance events. In his book *Lore of Running*, Noakes looks very thoroughly at this issue of training load as related to runners preparing for the 54-mile Comrades Marathon [1]. You might expect that for such an event volume of training would be the key factor in performance – but this, apparently, is not the case.

Noakes refers to the training principles of Bruce Fordyce, the most successful Comrades performer of all time. Although the race is run at the end of May, Fordyce kept to a relatively low mileage in January and February and did not start specific training for Comrades until the middle of March, when he put in a hard training period of eight weeks. Trials done by many researchers have confirmed that 6-8 weeks is the optimum period for heavy training. After that time, progressive fatigue sets in and little further improvement is made. Studies by Fordyce showed that:

- Training done six months or more ahead of the race have no relevance at all;
- The key training period need last only about eight weeks;
- Too many long runs are harmful rather than beneficial. Fordyce's normal mileage during the hard training period was about 100 miles a week, including one long run of 26-40 miles (42-64k).

for up to four hours. Emil Zatopek, the Czech runner, was known to have completed sessions of 20 x 200m, 40 x 400, 20 x 200m in a day. Tecla Loroupe, former holder of the women's marathon record, has done sessions of 20 x 1,000m.

However, the fact that something's possible doesn't make it desirable. Your training load at any one time must be related to what has gone before. If you suddenly increase it from, say, 40 to 100 miles a week, you will become very tired and prone to injury or infection. If, on the other hand, you build up gradually, increasing the load by 10 miles every two weeks and adjusting your sleep schedule and food intake to match the extra work, you can get up to 100 miles a week after 10 weeks with much less risk.

Older athletes should bear in mind, though, first that recovery takes longer and secondly that they have already acquired most of the benefits of prolonged training.

For all of us there is a level beyond which extra training is counter-productive, and the older you are the more quickly that level is reached. It is my firm belief that athletes should reduce their training volume as they gets older. A useful rule of thumb figure would be a 10% reduction every five years for those over 35.

Does running long distances slow you down ?

If the volume of running is high (more than 100k per week) and all the running is done at a slow pace (less than 4mins per kilometre), there is evidence that some of the intermediate muscle fibres become aerobic rather than glycolytic. This would restrict the ability of a runner to run faster than threshold pace and would certainly affect his sprinting ability and his performances in short (5k and under) races. However, the fact is that all elite distance runners avoid this problem by including speed work in their programmes.

Running extra miles at a slow pace can boost your aerobic fitness by increasing the number of small blood vessels (capillaries) within the muscles, and many athletes have found this helps them run faster over the shorter distances (3-10k).

Who has more endurance: older or younger athletes?

The myth that older athletes are less fit than younger ones has taken a long time to dispel. It dates back to the time when little training was done, so that younger people, with higher levels of growth hormone and less tissue damage, recovered more quickly from hard efforts. Now that the training process is understood, these expectations have been reversed.

If a runner performs well at, say, 21, we would expect him to perform better at 25 and, if he is an endurance runner, better still at 29. Studies on medals won in global events, by age category, show that 26-30 is the peak age for an endurance athlete, and there are many examples of athletes reaching their peak between 30 and 35. Endurance performance relies more on training than any other factor, and the older athlete, with greater discipline, is able to build this up.

There are examples of people who have trained very hard between age 18 and 21 and then reach a peak in their early 20s. But the fact remains that it takes several years to build your endurance capacity up to its maximum.

How long should the conditioning phase last?

Unless you are totally unfit, two weeks of slow conditioning work should suffice. This should be followed by 2-3 weeks in which better quality training is gradually introduced, leading into the pre-competition phase. However, people who need to lose weight through low level, fat-burning exercise may be advised to prolong the conditioning phase for 8-12 weeks until the target weight is attained.

How long do you stay conditioned?

Obviously this depends on how much exercise you take during the subsequent phases. If you do little training during the competition phase, you will see a loss of endurance after 6-8 weeks; but this is easily remedied by putting in one endurance session per week.

With running, where performance is quantifiable, there is no loss of fitness in the first seven days. Indeed, most long distance runners follow a 'tapering' programme in the two weeks before a big race, with little training in the last 4-6 days; and this rest allows them to perform better because stores of muscle and liver glycogen are at their maximum.

After that first week, fitness declines rapidly if no training is done. And a good rule of thumb is that for every week lost after the first seven days, two weeks of training are needed to restore the original level of endurance. There would be a noticeable lack of endurance after three weeks without training, when four weeks would be needed to get back to 'normal'; and after eight weeks without training or racing, an athlete would be regarded as being close to an 'untrained' state of fitness.

It is generally accepted in the running world that 6-8 weeks is an optimum period for intense competition, but this assumes the maintenance of at least two training sessions a week, one of them being an endurance workout.

'A good rule of thumb is that for every week lost after the first seven days, two weeks of training are needed to restore the original level of endurance'

The pre-competition phase

In this phase, which typically lasts for 6-8 weeks, you are trying to build up all the endurance factors that will be involved in the event, in event specific conditions.

The key factor here is your ability to maintain a high work rate when blood lactate levels are rising. This depends partly on lactate tolerance but mostly on the oxygen delivery system. The so-called middle distance events, lasting 2-10 minutes, make huge demands on the aerobic system, even though a lot of the energy is derived from anaerobic breakdown of glucose. Thus, much of the training in this phase is geared to improving aerobic fitness.

All training boils down to stimulus and response: what the training needs to do is to stress the system enough to produce a response but not so hard that it causes damage. When the body has responded, it can absorb more hard training.

The principles of interval training

The basis of modern speed endurance training was laid down by the German physiologist Reindell in the 1930s and is now used by athletes all over the world. It involves running at 90-100% of VO2max, which means around 5k or 10k pace, for short periods of time, then repeating these runs after a short recovery. According to Martin and Coe this has the effect of [2]:

- increasing the levels of both glycolytic and oxidative enzymes in working muscles;
- activating additional muscle fibres that are not stimulated by running at a lower intensity;
- increasing the blood buffering capacity, so increasing lactic acid tolerance.

Since it is possible to vary the number, the distance and the speed of the fast runs, as well as the recovery interval between them, the possible variations of interval training are infinite. It is advisable, therefore, to start with standard sessions related to your individual needs.

This training works in two ways:

1. By increasing VO2max. The training, which can be carried out on a running track, a bicycle, a treadmill or a rowing machine, affects the whole cardiovascular system so that the heart becomes stronger, the blood can carry more oxygen and the muscles can use the oxygen more efficiently;
2. By improving your speed at VO2max through a combination of greater muscular strength, better technique, improved efficiency and enhanced economy of action.

As a rule you should be able to start the next lap when your heart rate has dropped to 120 beats/min

Interval training techniques

The total distance covered in the fast runs should equal or exceed that of the event. So, for example, someone training for 5,000m might run 12-15 x 400m in a session, or 6-8 x 800m, or 5-6 x 1,000m. Someone training for a mile or 1,500m might do 8 x 400m or 6 x 500m or 5 x 600m.

The speed of the fast runs should be related to the your ability over that distance, so that someone hoping to run at five-minute mile pace would run at about 75secs per 400m, while a would-be six-minute miler would opt for about 90 secs per 400m lap.

The recovery time should be twice the running time to start with and can reduce with increasing fitness. Using a heart monitor makes the programme even more effective, since you can alter the pace to raise your heart rate to a desired level (90-95% of maximum) and use the consequent drop in heart rate as a guide to how much recovery time you need. As a rule, you should be able to start the next lap when your heart rate has dropped to 120 beats/min.

These principles apply whatever your age. As you get older, you may find that, for example, your 5,000m time increases and you need to adjust the speed of your training at 5k pace, but training volume and the recovery time should remain the same.

To give a personal example, I used to run interval sessions of 15 x 400m in 65 seconds a lap at age 30, with an equal-time recovery, and in 75 seconds a lap at age 50. By age 60 I found that I could only manage 12 x 400 in 84 seconds a lap, and at 70 I was struggling to do 10 x 400 in under 95 seconds. However, someone with more motivation would be able to run 15 x 400, but at a slower pace, equating to the 5k time.

Threshold and tempo training

Tempo training, related to the effort level of the competition, is very important in the pre-competition phase. Since the term means the same as 'race speed', it will differ according to the length of the race. For the 40-minute 10k runner, tempo pace is 4 minutes per kilometre, but for a 3:20 marathon it would be around 4mins 45secs per kilometre. The object here is to improve your efficiency at race pace which, of course, increases your endurance.

The length of the tempo run depends on the speed. Marathon runners do tempo runs in the range of 8-20k, but 10k runners can only manage efforts of 5-10 minutes at race pace.

Threshold training is a more specific concept since it refers to the pace at which your blood lactate levels start to rise. If you run faster than this pace, you start to build up an oxygen debt. For a runner, 10k pace would be above threshold – since lactate levels would build up during the race – but half marathon pace would be just below or right on the threshold. For a 90-minute half marathon runner, threshold pace would be 4mins 15secs per kilometre.

Threshold training has proven very effective and is widely used. Older athletes, who have already spent a lot of time on their feet, are probably better advised to spend time on threshold-pace runs rather than endurance runs, even though the latter may be more enjoyable.

Lactate tolerance training

For a 400m runner or hurdler, whose event lasts less than 60 seconds, endurance training involves repeated efforts at race pace over shorter distances, with long recoveries. Because the fuel used in the first few seconds is phosphocreatine, the recovery interval needs to be long enough for this to regenerate.

Typical lactate sessions for these events are described below.

1. Hill training

This should be done on a smooth but non-slip surface, with a slope of 10-15%. The walk or jog down will allow almost complete recovery on the first run, but as lactate levels build the effort gets harder and harder. The session should be done weekly in the conditioning and early competition periods. Hill running helps develop power and muscle elasticity, improves stride frequency and length and develops co-ordination. Repeated short uphill runs develop maximum speed and strength, while longer runs are excellent for cardiovascular fitness and strength endurance.

There are a number of ways to complete hill sessions that will help boost your performance:

- Short hills – 5-10 seconds to improve the phospho-creatine system of anaerobic energy production or 15-30 seconds to improve the lactic (glycolytic) power system;
- Whistle hills, controlled by the coach with a whistle, *eg* sets of 10secs, 15secs, 20secs, 25secs flat-out sprints, with an easy recovery jog of one minute between each and 3-5 minutes between sets;
- Short hills of 30-80m to develop speed and leg strength;
- Longer hills of 150-400m for strength endurance;
- Hills of 400-1,000m and hilly circuits over several kilometres for long distance and marathon runners;
- Hill bounding or hops and skipping over 30-80m. Like plyometrics, this improves the energy return as well as leg strength;
- Sand dune running, or resistance running with a weighted jacket, can be used as variations on the same theme.

2. Up the clock

The classic session here is to run fast over progressively longer distances – *eg* 100m-120-140-160-180-200, then down again, trying to continue running fast when tired. The recovery is normally a walk back to the starting point.

3. Short intervals

You do a short set of fast runs – *eg* 5 x 150m or 4 x 200m – during which lactate levels build up and phosphocreatine levels drop. You then have a long recovery of 10-15 minutes before repeating the set of fast runs.

4. Hard repetitions, long recovery

This simulates competition conditions even more closely. The session might be 3 x 400m or 4 x 300m at maximum effort, with 15mins recovery, or diminishing distances – *eg* 450-400-350-300m.

5. Weight training

The greater your muscle volume, the more fluid and buffering agents will be available to dilute the lactate. Larger, stronger muscles have greater lactate tolerance and thus greater endurance in short events.

Specific muscular endurance training

Where muscular endurance is a limiting factor, the muscle groups involved can boost their endurance by:

- increasing their strength
- enhancing their oxygenation
- improving their fuel supply
- using better technique to improve economy of effort.

There is a clash, though, between the need to improve strength and the need to boost the oxygen supply. If heavy weight training is used for the former, the consequent enlargement of muscle will leave less space for the blood capillaries and the additional mitochondria which carry out the respiration reactions. Each athlete must therefore choose his own path. In the running world, the New Zealander Peter Snell was a strongly-built tennis player, with big muscles, before he took up running; his coach countered these attributes with a high volume regime, which was very effective at improving his aerobic fitness. On the other hand, the slightly built Sebastian Coe, a champion at 3,000m as a 14-year-old, used weight training to build up his muscular strength for the shorter events at which he later excelled.

In terms of training, my recommendation would be to develop both types of capability at the same time, but to focus more on the weaker system.

The most useful training methods are:

- weight training
- interval training, using sport-specific routines
- some lower level training for general endurance, which embraces both capillarisation of the muscles and improvements in fuel storage
- specific work on technique to improve economy;
- speed training.

In the pre-season conditioning period, an athlete would need to weight train three times a week, concentrating on the muscle groups needed for his particular event, while also doing aerobic fitness training to develop the heart and blood supply. As the competitive season approaches, training moves more towards interval training – in this case taking the form of short hard efforts lasting 30 seconds.

Speed training to improve endurance might seem an anomaly. However, when intense exercise starts there is a thousand-fold increase in the process of glycolysis (the breakdown of glucose for energy). If the muscle did not learn to increase its rate of conversion of glycogen to glucose, it would soon run out of fuel.

Speed training also enhances the recruitment of muscle fibres. When all the muscle is brought into play, endurance is enhanced because some fibres can be rested while the others are working.

Strength training for endurance

For virtually all activities – with the exception of chess – it is impossible to separate the importance of endurance from that of muscular strength, and the ideal training regime incorporates both factors. For this reason, strength training in the gym is part of most training programmes; it also has the advantage of being easily quantifiable. The drawback is that many groups of athletes, particularly cyclists and long distance runners, dislike indoor training and are reluctant to admit that it does them any good. 'Kenyans and Ethiopians have no gyms', they say, 'yet look how well they perform.'

Nevertheless, research consistently shows that specific strength training brings about improvement. In a study on the link between strength training and endurance, carried out at the University of Chicago, nine men followed a 10-week, five-workouts-per-week incremental programme designed to strengthen their quadriceps muscles. Strength was measured at the beginning and end of the programme as the maximum amount of weight that could be lifted for one repetition.

Dramatic effects of incremental programme

The researchers found that the programme had dramatic effects, not just on muscular strength but also on cycling performance. VO2max during cycling had increased by 4% at the end of the study period, although VO2max during running remained unchanged! Endurance time improved by 47% while cycling (from 278 to 407 seconds) and by 12% while running (from 291 to 325 seconds)! Interestingly, though, the participants had not cycled – or, indeed, run – as part of the research.

'Many groups of athletes, particularly cyclists and long distance runners, dislike indoor training and are reluctant to admit that it does them any good'

The main conclusion, since backed by further studies, was that strengthening their quadriceps enabled the subjects to cycle more efficiently. No doubt a similar effect could have been produced by assigning them to a regular routine of riding on hilly courses; nevertheless, this research carries an important message for athletes in all disciplines – that strength work in the gym can also bring endurance benefits.

Strength training is particularly useful for older athletes, since it has long been recognised that, in the absence of any corrective exercise, strength declines a bit more each year.

Weight training has its drawbacks, since it is not easily available to everyone and is not suitable for large groups.

However, circuit training, which involves strength training with and without simple weights, as well as aerobic fitness work, can be tailored to the particular needs of a sport.

Circuit training

An interesting study on circuit training for strength was carried out in the 1980s at the Institute for Aerobics Research in Dallas, Texas. This involved a large group of people (41 men and 36 women) on a 12-week programme. They were divided into three groups, as follows:

- One group carried out a circuit session consisting of three circuits of 10 exercises per workout, three times a week;
- A second group took no exercise, serving as 'controls';
- The third did the really interesting workouts – a combination of circuit training and running at about 8:30 per mile pace.

Encouragingly, not a single person was injured during the training; and, indeed, low injury rates are one of the most attractive features of circuit training. Since running and resistance work are both moderate, there are few overuse injuries and little risk of severe muscle strain or back injury.

After 12 weeks, both the strength-only (SO) and strength-plus-running (SPR) groups had lost the same amount of weight and a similar amount of body fat, and added equivalent amounts of muscle tissue. Both groups also improved bench-press and leg-press strength to a similar extent.

In terms of aerobic fitness, the SO people increase their endurance while running on the treadmill by about 12%, even though they didn't run at all, but the SPR group improved treadmill endurance by 19%. Similarly, SPR group members boosted VO2max by 17%, compared with just12.5% in the SO group.

The gains in the SPR group are particularly interesting. Even though they were running slowly for a total of just 15 minutes (10 reps x 30 seconds x 3 circuits) three times a week,

The all-round fitness circuit

There are an almost infinite number of possibilities, but the following circuit workout will boost your fitness dramatically, using very simple equipment. The 400m run doesn't have to be on a track: it can be any loop that takes 1-2 minutes to run at your 5k pace; but you should use the same loop each time in order to compare your times.

Warm up with 10-15 minutes of easy jogging, swimming or cycling, and then perform the following exercises in order. Move quickly from exercise to exercise, but don't rush the exercises themselves; the idea is to do each exercise methodically and efficiently, then start the next almost immediately.

1. **Run 400m** at your current 5k race pace; if you're a swimmer, swim 100m at high intensity; if you're a cyclist, pedal for 1,600m at high speed
2. **5 chin-ups** You will need a 'chinning bar' for this: hang from the bar with palms facing your body, then pull up until your chin is level with the bar. Lower to straighten your arms
3. **36 abdominal crunches** Lie on your back with knees bent and feet flat on the floor. Cross your arms over your chest and use your ab muscles to lift your torso up and ahead as far as possible, then slowly return shoulders to the floor
4. **15 squat thrusts with jumps (burpees**) Start in the press-up position (*see below*). Bring feet towards hands in a jumping motion, keeping knees within arms and back flat. Keeping back straight, jump up and resume the squat thrust position before returning to your start position
5. **15 press-ups** Lie face down with your hands flat on the ground, shoulder-width apart. Full extend arms to raise your body, then lower
6. **30 fast body-weight squats** Stand erect with feet directly below your shoulders; go into a squatting position, with thighs parallel to the ground, then return to standing position
7. **Repeat step 1**
8. **12 squat and dumbbell presses (with 10lb dumbbells)** Do the body-weight squat (*see above*) holding dumbbells in your hands, directly in front of your shoulders, hands turned inwards so that palms face each other. Once you've returned to the standing position, 'press' the dumbbells directly overhead, straightening your arms in the process, then return them to shoulder position to complete one rep
9. **10 feet-elevated press-ups** Normal press-ups, with feet elevated on a bench, chair or wall
10. **36 low back extensions** Lie on your front, arms by your sides and hands extended towards your feet, with palms touching the floor. Contract the muscles at the back of your neck so you

are gazing forward and upward. Contract your low back muscles to lift your trunk well off the floor, then slowly ease back down

11. **15 bench dips** Sit on a bench or chair with hands at your sides, gripping the front edge of the seat. Keeping hands in that position, slide forward off the chair, with your feet as far forward as possible, so that all your body weight is supported by your hands and heels. Lower your butt to or near the floor, then return to starting position
12. **15 lunges with each leg** Start with erect posture, with feet under shoulders. Step forward with one foot, then immediately assume a squatting position so that the thigh of the forward foot becomes almost parallel with the ground and return to starting position
13. **Repeat step 1**

If you are using a heart monitor, record your maximum and mean heart rates during this sequence. Allow yourself a brief recovery, then repeat steps 2-13 again (for two circuits in all), then cool down with about 15 minutes of light jogging, swimming, or cycling.

in addition to their three 15-minute bouts of resistance training, they made great gains; higher intensities of running would have no doubt produced even greater improvements.

The continuous nature of circuit training tends to keep heart rate and oxygen consumption high throughout the workout. You are always doing something, so the muscles keep using oxygen to furnish the necessary fuel and the heart keeps pumping oxygen to the muscles.

The lesson, of course, is that if you want your circuit training to improve you aerobically, you should not consistently use very heavy weights.

The value of circuit training

Endurance athletes may wonder what the series of exercises described in the panel above have to do with running, cycling or swimming? In fact, although you may think that press-ups are only good for strengthening the arms and shoulders, they are actually whole body exercises because they force the core muscles in the hips, abdominal, and low back areas to support and stabilise the body while the trunk is moving up and down.

And if you don't think that 'burpees' work your whole body, try reeling off 15 of them right after you have run 400 metres hard and completed several chin-ups and a set of abdominal crunches!

The workout looks easy, but most endurance athletes find it to be far from easy when they actually try it. A circuit of this type is particularly useful for older athletes because it maintains all the muscular strength that tends to decline with age and covers all the muscle groups.

Cross training

To set the value of cross training in context, let's consider the case of an overweight 40-year-old man who wants to get fit after taking no regular exercise for five years or more.

His basic needs are:

- to reduce body fat
- to boost cardiorespiratory (aerobic) fitness
- to enhance endurance.

The last two of these are closely linked: in the early stages of training, the running will be slow to build up endurance, but it will still improve CV (cardiovascular) fitness, while more intense CV workouts later on will also improve pure endurance. The would-be athlete may well need to improve other aspects of fitness, such as flexibility, strength, power and speed, but these may be addressed in more detail once a base of fitness has been established.

The most specific way for our man to develop endurance would be to perform lots of slow continuous work – on foot or on a bike – which would also help him lose fat. The trouble is that, being on the heavy side, even if he runs on grass in well-made shoes, there is a fair risk that he will injure his muscles and joints. It makes sense for him to vary his workouts with some running, some cycling to give his legs a rest from pounding, some gym work and some swimming. All these activities will help him lose body fat and increase cardiovascular endurance, with a reduced risk of overuse injury.

In fact, it is the avoidance of overuse injuries that is one of the strongest arguments in favour of cross training. You can do extra endurance work, with less strain placed on the same muscles and joints, while at the same time giving your heart and lungs a perfectly adequate workout.

'The avoidance of overuse injuries is one of the strongest arguments in favour of cross training'

Cross training for endurance athletes

It sometimes happens that an endurance runner would like to do more training but knows from experience that once the weekly mileage creeps beyond a certain point, say 50 miles a week, the injuries start to come thick and fast. Non-specific training is a good way of increasing the training level with a reduced injury risk. Cycling, for example, allows you to work on the heart and lungs without subjecting the joints to pounding.

But how useful are such methods for boosting running performance itself? Research suggests that cycling is very useful. One study carried out at California State University found that runners who were split into two groups – one running and the other cycling, both at the same intensities for nine weeks – performed equally well in a subsequent running test.

The study also showed that, for runners, tough cycling was a good way of not just maintaining but actually boosting running fitness. However, the converse was not true and the increase in cycling fitness in the group who ran was not nearly as marked.

When I was carrying out a survey for my book *Running over Forty*, I found that the most successful runners, in terms of the duration of high level performance, were those who did regular cross-training, combining cycling and either swimming or weight training with a reduced volume of running. The running normally included two hard sessions a week, one hill training or interval session and one session of longer running, either a sustained tempo run or long repetitions, *eg* 4 x 1 mile. This combination maintained aerobic fitness and muscular strength, with less overuse injury than was found in those who did nothing but running.

Benefits of aqua-running

This means running in a pool, usually wearing a buoyancy vest which supports most of the body weight. The general consensus of recent research is that aqua-running will not give the same intensity of training as normal running but is still a suitable alternative, given its low impact nature. It is worth noting, however, that this kind of running is more effective without a buoyancy aid.

Aqua-running really comes into its own when an athlete is injured, because there is no impact stress. With practice, it is possible to do interval training in the pool, running hard for 30-60 seconds, with an equal time recovery. It is best to use a 'wet vest' for support to start with. If you have to continue with aqua-running and want to work harder, you can then discard the vest.

Heart rates and cross-training

If you do cross-train and use heart rate as your guide to intensity, it is important to remember that maximum heart rates, and therefore training ranges, are likely to vary according to your mode of exercise.

You can normally expect higher heart rates when you run than when you cycle or row. The reason for this is quite simple: when you run, you support your body mass, lifting it up with each stride, while with rowing and cycling you are seated and your body mass is supported. This makes the energy demands of running a little higher. Although there is enormous individual variation, it is usual for the heart rate to be about 10 beats per minute higher during running than cycling for each effort level, and this should be borne in mind when selecting training intensities.

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Chapter 6

Endurance training by sport

This final chapter describes detailed endurance training schedules for a range of the most popular sports, starting with the classic endurance disciplines of running, cycling, rowing and triathlon.

Endurance training for runners

Conditioning

A distance runner over 40, aspiring to reach national class, might set a target of running 50 miles a week through the cross-country (winter) season, occasionally hitting a peak of 60 miles. The training week would consist of five days of running 6-10 miles a day, one day's rest and one long run of 12-16 miles. The conditioning period traditionally involves a four-week build-up of steady running in September, doing 30, 35, 40, then 45 miles, increasing the long run from 6 miles up to 12.

An elite Master runner in Britain might have three peaks in the year, aiming for Masters cross-country events in October and November, inter-club cross-country championships in February and March, then road racing, up to the half marathon distance, followed by track championships in late summer. Weekly mileage will be in the range of 60-80 miles.

Pre-competition period

Most coaches and researchers see eight weeks as the maximum period for this phase. The Master runner, like the normal club runner, might introduce one 'quality' session a week in the second two weeks of the conditioning period, then move to a regular pattern of two quality sessions a week, plus a threshold run and a long run. If the quality sessions include a hill session (say 12 x 200m uphill) and a repetition session of 4 x 1 mile, and the threshold run is five miles, total 'quality' mileage will amount to 10.5 miles out of 50.

Since the key components of the next phase are always introduced in the previous one, there will probably be only four or five weeks between the end of the conditioning period and the introduction of early-season competition.

Elements in the training

The crucial sessions in pre-competition training should be related to the event. From the endurance angle, it is important to maintain the total weekly load, but not to add in extra endurance sessions. Occasionally, though, an endurance test may be substituted for a normal session to maintain the athlete's confidence.

In order to cover all aspects of endurance – speed endurance and lactate tolerance as well as aerobic conditioning – all top level runners now use 'multi-pace' training. A 1,500m runner will do some training at 400m and 800m pace for speed, as well as some sessions at 5k and 10k pace for aerobic conditioning. His key sessions, though, will be at 1,500m race pace.

A common pattern in the pre-competition phase is 2-3 weeks hard, one week easy. The patterns within each week are as follows:

- **Normal week** Easy, moderate, hard, easy, moderate, hard, long;
- **Hard week 1** Hard on Tuesday, Thursday, Saturday, easy on the other days;
- **Hard week 2** Easy, hard, hard, easy, moderate, hard, easy/long;
- **Easy week** Rest on Monday, one fast session on Tuesday or Wednesday, easy running on the other days before a trial race on Saturday.

For a 5k runner, the hard sessions will include one 10k and two 5k sessions over the first three weeks, plus a faster 3,000m or 1,500m session at race pace.

- **The 10k sessions** will be 8-10 x 1,000m, or 5-6 x 5mins or 3 x (2,000 + 1,000) all at 10k pace;
- **The 5k sessions** will be 3 x 5 x 400m or 5 x (800 + 400) or 5 x (1,000 + 400), with the longer runs at 10k pace or faster and the 400s at 5k pace, all with 2mins recovery; An alternative session is 400-600-800-1,000-1,200-800-600-400 at 5k pace, with 60secs recovery per 400m;
- **The 3k sessions** will be 6 x 600 at race pace, with 90secs recovery;
- **The 1500m sessions** will be 6 x 500m (2mins recovery) or 2 x 5 x 400 (90secs recovery) or 3 x (700+ 300), with 2mins and 3mins recovery respectively, all done at race pace.

The rest of the running is mainly recuperation, running really slowly after the hard sessions. A moderate session means either threshold running or fartlek.

Pre-competition – a typical week's training

Mon	6-7 miles easy
Tues	5 x 1 mile at 10k pace, 3mins rest
Wed	7 miles steady pace
Thurs	Warm-up, 8 x 600m or 12 x 400m on grass
Fri	Rest or morning jog of 3 miles
Sat	Warm-up, 2 x 15mins threshold pace
Sun	12-15 miles easy, off road

Competition

The normal pattern, when racing on a Sunday, would be to train normally Monday through Wednesday, do a short sharp session on Thursday – *eg* 6 x 400m at 5kpace – rest on Friday, then on Saturday do a warm-up and some fast striding, *eg* 6 x 150m, with plenty of recovery. To maintain the endurance, you either have to run a few miles after your race or put in a long slow run on the following Monday or Tuesday. Choosing between the two can be difficult and should depend on how you feel after the race and the importance and proximity of the next race.

The guiding principle for older runners is not to train hard when tired, so it would probably be best to skip the long run and concentrate on recovering between hard races. The races themselves act as training, and there should be an opportunity for an endurance run at least once every two weeks.

Endurance training

"The guiding principle for older runners is not to train hard when tired"

Long distance runners, racing at distances between 10k and the marathon, will use the same principles set out above, but need to take account of the fact that much more of their racing time is spent at speeds well below maximum oxygen Intake. Aerobic conditioning will be achieved by training at 5k and 10k speeds, and endurance – in terms of heat tolerance and fuel management – can be added to the mix by running at half marathon and full marathon pace.

An effective pattern here is to follow a three-day microcycle of easy-moderate-hard, with a long slow run every seventh day. The easy day might be a total rest, a three-mile jog or even two easy five-milers, depending on how tired you feel. The moderate day should include one easy run and one session of fartlek or threshold running, *eg* 2 x 15mins at threshold pace. The hard days will include one 10k session – *eg* 8-10 x 1,000m with a 600m recovery jog – and either a 5k session, as described above, or a tempo session for half marathon runners, *eg* 3 x 5k on road or trail.

Marathon training

It is here that the Master runner can really shine, since training, pace judgement and experience are of prime importance. The best over-40s have clocked times in the 2:10 – 2:12 range. Marathon runners, who normally have two peaks in a year, need a specific training pattern. Long recovery periods of about four weeks are recommended after races, but this does not mean that the marathon training should last for five months; experience has shown that boredom and injury tend to set in if high mileage is maintained for a long time.

The methods used by Master runners will differ only slightly from those relevant to the under-40s. Assuming that the last two weeks will be used for tapering, the hard training period should last for about eight weeks before that, and the conditioning period for the previous 4-6 weeks, making a total of 14-16 weeks of marathon preparation.

To duplicate race conditions, marathon runners of all ages have to run hard as well as long. The long run is not merely for building endurance: it is a race specific session. While the amateur marathon runner will build the distance of the long run over 12 weeks, running slowly, the really serious runner will probably have covered 24-26 miles in a training run during the conditioning period.

In pre-competition, the idea is to increase the pace of the run. Italian coaches use a session called the 'progressive run', in which each 10k gets faster. The first 10k is run at a comfortable pace, the next at the intended marathon pace and the last even faster than that, with a 3-5k stretch added on for cooling down.

Other variations on the theme of 'running hard when tired' include:

- **The loop system**, used by the American runner Alberto Salazar. You do a four-mile loop, at slower than race pace, then comes back to the track and run a fast mile before going out on the loop again;
- **The 'fast and slow' session** After 3-4 miles steady, you alternate fast and slow miles for 10-12 miles, then ease down. A variation of this is to use a 3k loop and do 2k fast and 1k coasting;
- **The tempo run** This is usually 10-15 miles for marathon runners, starting at just below marathon race pace, then picking up speed mile by mile.

The competitive season

The normal pattern for road runners is to race once a week for most of the year, except for a few weeks in the heat of the summer, with a possible break in the depths of winter, if it is severe.

The special case of ultramarathons

Ultramarathons present special problems. Proportionately, these races tend to attract more older runners, who can make up with additional training what they have lost in speed. Mental strength, fuel storage and economy in the use of fuel are the important factors, and older runners can excel in all these areas.

The most popular 'ultra' event in terms of sheer numbers is the 54-mile Comrades Marathon in South Africa, which has been going for more than 80 years. Because of the longevity of this event, South African sport scientists have a great deal of experience in ultra endurance training. They have found that the most effective training differs little from standard marathon training, but with fewer quality sessions and more long runs. While the marathon runner rarely reaches 26 miles in his long runs, Comrades runners regularly put in runs of 30 or 40 miles.

For the most successful Comrades runner, Bruce Fordyce, the conditioning phase involved running less than 500k (312miles) a month in January and February, building up to a peak of nearly 500 miles a month in April, then tapering off during the last three weeks of May.

Compare this with the training of Richard Nerurkar, Britain's leading marathon runner in the 1990s (best time 2:08.36), who was coached by the author. His winter conditioning period was normally spent at altitude in Kenya, in December or January depending on the date of competition. His mileage would then build to 110-120 miles a week.

The twelve-month competitive season is clearly not conducive to development, except in the first couple of years. Almost all runners periodise their year, as described in the previous chapter, but the competitive season can still extend over many months in winter, and the questions this poses are:

1. How long can you go on competing without performance falling off?
2. How can you maintain fitness during the competitive period?
3. Should you be doing 'quality' training for speed or longer training to maintain endurance?

These questions become more important as the level of competition rises, forcing the athlete to work more intensely. They also become more pressing with age, since older runners recover more slowly from hard races and find it difficult to push themselves really hard on a regular basis. The harder you train and race, the greater your loss of fluid and minerals and the greater the stress on your whole body.

For Masters, the answers to the above questions are:

1. With appropriate breaks, the right training and proper nutrition, you can go on competing for up to 16 weeks, but this should be divided into periods of three or four races, interspersed by two-week breaks.
2. The key to maintaining fitness lies in seeing the races as very intense training sessions. The intense stimulus will be followed by an appropriate response, providing you allow enough time for recovery, which will be hastened by the use of replacement fluids after races.
3. The races act as the high-quality sessions. As soon as muscle glycogen levels return to normal (for which muscle soreness, tiredness, stiffness and body weight can be taken as guides), endurance training can be resumed. The runs should be at slower than threshold pace to avoid lactate build-up. The length of the run must be related to the time available before the next race.

A common mistake is to insist on doing a long run the day after a very exhausting race. The further loss of fluid and glycogen imposed on muscles that are already dehydrated and depleted slows down recovery rather than assisting it. On the other hand, a long run after 48 hours of recovery will stimulate capillary blood flow and flush away any remaining waste products as well as being mentally refreshing.

Tapering and performance

The build-up of endurance undoubtedly improves performance, but many athletes spoil their chances by doing too much training just before the event. In the marathon, where high volume training is accepted, the conventional taper involves reducing the volume by 50% in the penultimate week and doing very little (no more than 25% of normal volume) in the week before the race.

The questions which remain are:

- Should you rest every other day, or train lightly very day?
- Should all the running be easy, or should it include some speed work?

Several researchers have considered these question. One group of swimmers found that when they cut back their training volume from six to two miles a day, performance levels rose after two weeks and remained constant for many weeks afterwards. Another research group confirmed this finding, but concluded that two-and-a-half weeks was the longest the reduced training volume could be maintained before performance levels fell off.

Although this research dates back to the 1980s, its conclusions have has not been generally incorporated into training. Athletes addicted to the 'more is better' philosophy find it difficult to accept the idea that less training could make them stronger or faster, and Master runners tend to be more addicted than most!

"Athletes addicted to the 'more is better' philosophy find it difficult to accept the idea that less training could make them stronger or faster"

The principle of delayed benefits

However, the fact remains that successful tapering is based on a training principle that exercise physiologists have known about for a long time. This is that, with a few exceptions, the physiological benefits of a training session don't usually appear until at least 10-14 days after the workout because the body needs that time to adjust and rebuild after the strenuous exercise. This leads to the logical question: what is the point of working so hard in the last two weeks before your big competition when the benefits won't appear until after the event is over?

To summarise, research has shown that if you cut back on your training volume by 90% and let fairly intense work make up most of what is left, you may be astoundingly better after just one week.

This also ties in with my own practice when coaching top class athletes. For marathon tapering, coming off training levels of over 100 miles a week, we aim for no more than 75%

of that volume with three weeks to go, no more than 50% in the penultimate week, and only 2-3 miles a day in the last six days. We always build in a session of fast strides – 4-6 x 200m – on the day before the race to stimulate enzyme production.

Principles of cycle training

The same physiological principles apply to cycling as to running, swimming or rowing:

1. Training is specific to the event. This means that the more training you do at race speed, the more effective it will be;
2. Long training rides at submaximal pace will increase your aerobic capacity and endurance;
3. Repeated hard efforts against resistance will increase leg strength and lactic acid tolerance. The same effect is produced by 'cadence variation' sessions: after a period of riding at a comfortable cadence, you speed up and maintain the new cadence for, say, 10 or 15 minutes before reverting to the comfortable speed;
4. Up to a certain level, the more hours you spend in purposeful training, the better you will become.

Cycling as part of a fitness programme has much to recommend it:

- It is more interesting than other endurance activities because you cover more ground (unless you are on a static bike);
- It is less damaging for beginners because there is less impact stress;
- It is easy to plan and quantify your progress because speeds, distances and heart rates can all be measured;
- It is excellent for cardiovascular training because high heart rates can be maintained for longer;
- It is easy to fit into daily routines because you can use your bike for regular transport.

Cycling beginners

In the early stages it is a good idea to cycle 3-4 times a week for just 20-30 minutes a time. This gets you used to handling the bike and to the different muscular demands. After two weeks, you can introduce 40-60 minute rides once or twice a week and also start to increase the effort level, working harder on the hills or wherever the route permits more speed.

At this point it is helpful to set targets, either by timing yourself around certain courses (15-30 minutes in duration) or by using a heart rate monitor. In the latter case you would aim to ride for a certain length of time within a given heart rate zone – say 75-85% of maximum. A 40-year-old man with a maximum heart rate of 180 would therefore be riding at an HR of 140-148.

The best way to measure your increasing fitness is by combining the two targets – and if you are using a static bike in the gym, this is really the only way of making it interesting! If you can cycle 8k/5miles in around 20 minutes, and measure your HR while doing so, you can then track your progress week by week, either by riding for a longer time at the same HR, which shows an increase in endurance, or by completing the course in a faster time with the same HR, which shows an increase in aerobic capacity.

It is best to set a programme for no more than three months at a time, with some definite goals to work for. These might include:

- pushing the volume of training up to a certain level, *eg* four hours a week;
- achieving a target time for 8k/5 miles or 16k/10 miles;
- achieving a personal best for a continuous ride, say 50k/30miles.

"Two hours a week of strenuous exercise is all you need to maintain a healthy heart, but in the world of cycling this is nothing"

Making progress

The easiest way of doing this is to meet up with other people who share your interests, maybe at a gym, in a cycle club or through a charity cycling event. How far you go is up to you. From the health and fitness angle, two hours a week of strenuous exercise is all you need to maintain a healthy heart, but in the world of cycling this is nothing. From the endurance angle, you can work towards doing regular three or four-hour rides at the weekend.

Triathlon: the most testing sport

This is the most gruelling sport of all, testing, as it does, so many aspects of fitness, needing strength in every muscle group and demanding hours of intense cardiovascular effort. The Olympic distance triathlon is the equivalent of running a marathon, and the Ironman, for most people, takes 10-12 hours, so endurance is very important. On the credit side, though, is the fact that switching the training from swimming to cycling, cycling to running and back again means many fewer overuse injuries.

We can assume that anyone taking up triathlon already has a background of training and competition in one or more of the three disciplines and so is already reasonably fit and accustomed to regular training.

The basic principles are:

1. Aim to practise each discipline at least twice a week;
2. Work to a training plan of at least 13 weeks before a major event;
3. Measure training in terms of hours and minutes, divided roughly into 35-40% cycling, 25% running, 15-20% swimming and 15% gym work. In the last six weeks the gym work will taper off and the other three disciplines will get an extra 5% of your time;
4. Increase the total training hours month by month;
5. Think in terms of 2-3 weeks hard followed by one week easy;
6. One of the cycling sessions should be done after a swim and one of the running sessions should be done after a bike ride. However, the preliminary session need not be a full one.

The key training principles are:

1. Start with low pressure aerobic training, building up the time and getting accustomed to regular training;
2. Start to introduce quality workouts in each discipline, getting your heart rate up into the training zone;
3. Increase the volume of the quality workouts as well as the distance of the long sessions;

4. Before stepping up the training still further, have a week with the emphasis on basic endurance – *ie* hours of training – rather than quality

Short-course training programme

Aim for 6-8 hours per week, as follows:

Mon Rest day
Tues 20mins cycle to running club, 40mins steady run, 10mins easy cycle
Wed Swimming day. 30mins steady, plus 20-30mins weight training
Thurs Running day: 40mins training plus a 15-minute swim
Fri Cycling day: 20mins before work, 40mins after work, plus weight training 15-20 mins
Sat Swim and cycle, *eg* 20mins swim, quick transition and 90mins on bike
Sun Cycle and run, *eg* 15-20mins on bike, then straight into 60mins run
Totals Bike 3 hours, swimming 1 hour 15mins, running 2 hours 20mins, weights 35-50mins

Progression: In the first month, start with one discipline per day, *eg* running Tuesday and Thursday, cycling Friday and Sunday, swimming Wednesday and Saturday. Introduce one extra session each week. Every two weeks, try to improve the quality or the volume of one session, while keeping the others the same. For example, if you have only a limited time for swimming, make one session a week an interval session. If you want to improve endurance, add to the distance of your long bike ride one week, and two weeks later increase the length of the long run. If you want to improve aerobic fitness, make one of your running days an interval session (*see page 76*), or one of your cycling days a cadence-variation session (*see page 97*). Remember that consistency of training is worth more than the occasional mega-effort.

Long-course training programme

Aim to build up from eight hours to 15-16 hours a week. Time is obviously the problem here, so try to set aside one midweek day as well as the weekend for high volume training. Cycling to and from work allows for better time management, so that 60-90 minutes of commuting time becomes 60-90 minutes of training time. If there is a gym near your workplace, it should be possible to fit 20-30 minutes of swimming or weight training into the lunch hour, say twice a week.

Weekly programme

Tuesday to Friday 60-80mins daily cycle commuting

Mon	Recuperation day: 15-20mins swim
Tues	Lunch hour: 20mins weight training; pm running: warm-up plus repetition session, *eg* 5 x 1 mile (3mins recovery)
Wed	Swimming: 30mins
Thurs	Lunch hour: 20mins weight training; pm: running, *eg* warm-up plus 2 x 20mins threshold run (3mins rest) or 45mins tempo run
Fri	Swimming: 30mins
Sat	Swim and cycle: 20mins hard swim, quick transition plus 60-120mins on bike
Sun	Cycle and run: alternate long (2-3 hours) bike/short (40-60 mins) run with short (60-90mins) bike/long (90-120mins) run
Totals	Running 3-4 hours, swimming 1 hour 40mins, cycling 7-10 hours, weight training 40mins.

Progression: The daily commuting keeps the volume of cycle training high, so you could only progress by improving the tempo of the weekend rides. If circumstances permit, you can boost total swimming time to two hours and total gym work to 60-90 minutes in the non-competitive season. Research supports the practice of combining cycling and running in the same training session, as the transition between bike and run seems to alter the physiological stress of running.

The special demands of rowing

Some of the highest maximum oxygen intake figures ever recorded have been in rowers, because rowing makes demands on all the major muscle groups – legs, back, abdominals, arms and shoulders. Since most competitions are over 2,000m, the cardiovascular demands of the sport are similar to those of middle distance running.

Specific training

The most effective training is specific to the event, particularly with rowing or sculling, where technique is of crucial importance. Ideally, some in-the-boat training should be done all the year round. Failing that, use of the tank or the rowing ergometer is almost as good. Once you are accustomed to working for 15-30 minutes, you can move on to a form of interval training up to three times a week, putting in efforts at race speed, with short recoveries. The next step up is repeated 'pieces' of a few minutes' duration. Over-distance rows are useful for building confidence, but are no substitute for working at the correct striking rate.

Running training

Again, the most effective work is interval training – sets of runs over one, two or three minutes, with equal-time recovery, at close to maximum effort. Longer, slower running is good for building fitness from a low level, for maintaining fitness, and also for improving leg strength, but it is no substitute for rowing training because it does nothing for the upper body. Once you can cope with running steadily for 30 minutes, it is time to move on to more demanding training.

Weight training

Because body weight is supported and the weight of the boat is a constant, there is an advantage to being big. For optimum performance, muscle bulk and muscle strength are both crucial, so weight training forms a major part of the preparation.

It is vital to select the right exercises, perform them at the right intensity and place them within a progressive and carefully structured weights programme. Olympic rowing coach Terry O'Neil believes that a weight training programme for his sport should mirror actual race requirements as closely as possible (a principle that should always be adhered to, regardless of sport). This means that the exercises selected must:

- be relevant to rowing
- be performed ultimately at a pace equivalent to the actual stroke
- create conditions that mirror the heart rate levels sustained during a 2k race;
- reflect the time it takes to complete the race distance.

In his most specific six-week weight training microcycle, O'Neill reduces the amount of weight the rowers attempt to between 15 and 30kg. This is so that they can complete 45 seconds of continuous rhythmic exercise at a rate similar to the stroke in a race.

At the end of each station, athletes move on to the next exercise without stopping, providing a total of eight minutes of work, during which time the heart rate will rise to 85-95% of maximum. O'Neill gets the athletes to rest for two minutes at the end of each circuit. The aim is for them to complete three of these circuits workouts per week during the first three weeks, and four circuits in weeks four, five and six of this microcycle. The specific exercises used are:

- high pulls
- press behind neck
- front curl
- bent over rowing
- lateral dips (side bends) to right and left
- squat
- bench press
- clean and press
- jack knife crunch
- bench pull
- hyper-extensions.

Combined skills for footballers

The basic principles apply to all codes: soccer, rugby, Australian Rules and American football. Some demand more muscular strength, some more speed and some more aerobic fitness, while within each sport the needs of forwards and backs will differ. In terms of endurance, players have to run as far as 10k during a game, often in hot conditions; most of this is at jogging speed, but a small proportion is in the form of short sprints with short recovery periods, so cardiovascular fitness is very important.

Footballers need a combination of technical, tactical and physical skills to succeed. It is odd, therefore, that football research has tended to focus on technique and tactics, with little emphasis on how to improve basic fitness.

In research referred to in Chapter 2, interval training boosted footballers' overall ability to play at high intensity: after eight weeks of interval work, they were able to perform at an average of 85.6% of max heart rate during their games, compared with 82.7% beforehand; they also spent 19 minutes longer than controls in the high intensity zone (*ie* above 90% of max heart rate) during an actual game.

Benefits of interval training

Of course, interval training is not a panacea, and sprint speed, squatting strength, bench-press strength, jumping height, kicking velocity and the technical shooting and passing test were unchanged by the aerobic work, as you might expect. Nevertheless, a very simple interval training programme (with just two workouts per week and four 4-minute intervals @ 90-95% of max heart-rate per workout) produced some dramatic improvements in overall play.

To put it simply, boosting VO2max, lactate threshold and running economy with interval routines gave the players an enhanced ability to cover longer running distances at higher intensities during games, to be involved with the ball more frequently and thus to play a greater role in deciding the outcomes of competitions.

What other interval workouts might be beneficial? Clearly, some of the renowned French scientist Veronique Billat's 'vVO2max'* sessions would be helpful, since they are very intense and lead to enhancements in VO2max, lactate threshold, and running economy.

Two of these workouts are particularly beneficial:

1. **The 30-30** For this workout, you simply alternate 30 seconds of running at close to max intensity with 30 seconds of easy ambling. Initially, you should go for 10 reps, but as aerobic capacity improves you can simply keep going until fatigue kicks in;
2. **The 3-3** This is similar, except that you alternate three minutes of hard running with three minutes of jogging. The pace for the strenuous three-minute intervals should be determined by the best possible speed achieved during a six-minute test (otherwise, at 5k pace). Few athletes should try to complete more than five three-minute intervals per workout.

"The only argument for steady running might be in the off-season to make sure that players are fit enough for the interval training"

I have not come across comparisons between the effectiveness of interval training and steady running for footballers, but, given that much of their training time is spent on ball skills and match practice, interval training makes better use of the time. The only argument for steady running might be in the off-season, to make sure that players are fit enough for the interval training.

The older a player gets, the more important it is to maintain strength and fitness, which is why older players should include regular interval training in their programmes. Their training performances will tell them exactly where they stand.

The problem of body weight in rugby training

The problem with rugby training is that body weight, so important in scrummaging and tackling, has a negative correlation with aerobic fitness. VO2max is measured in mls

*vVO2max means velocity at maximum oxygen consumption and is a better measure of ability than VO2mmax alone.

of oxygen per kg of body weight per minute. If a 90kg player has a VO2max of 60 mls/kg/minute, his oxygen intake must be 60 x 90mls, which is 5,400. If this man puts on 10kg without improving his fitness, his VO2max will drop to 5,400/100, which is 54.

An analysis of Welsh Division I players showed the power and strength needed to compete at the highest level (2). Researchers at Loughborough and Cardiff found that forwards had respective average height, weight and body-fat values of 186cm, 97kg and 11.3%, while for backs the average values were 178cm, 79kg and 8% respectively. Lean tissue obviously predominates, with substantial muscle mass observed among the forwards. A sprint shuttle run totalling 40m, with two turns, showed the backs to be better at sprinting and more agile than the forwards (8.4secs compared with 8.7secs).

‘The quest for increased power and speed through the acquisition of greater muscle mass must allow for the retention of as much aerobic fitness as possible’

However, the VO2max values of 52 and 56 for forwards and backs respectively were not as high as expected or desired. Although the most important periods of rugby play are at an intensity that requires anaerobic energy production, the ability to recover sufficiently between plays depends to a large extent on the body's ability to deliver oxygen to the muscles. The implications for training are that the quest for increased power and speed through the acquisition of greater muscle mass must allow for the retention of as much aerobic fitness as possible. The programme will differ according to the strengths and weaknesses of each individual.

Conditioning period

Whatever the code and whatever position, the player must be able to keep going for 90 minutes. As we have seen from the research on Norwegian footballers (*see page 41*), this involves running 8-10k (5-6 miles) in each game, but at a variety of paces. Research has also shown us that for endurance in these sports, what really matters is VO2max. A gradual increase in the volume of fitness training will bring all players to the point where they can cope with the duration of the game, but training must at the same time make demands on their aerobic fitness and simulate the stresses of a match situation.

Interval training

For older players wanting to maintain fitness and endurance, interval training is essential, during both the conditioning phase and the playing season. The following sessions, performed once or twice a week, are appropriate:

- **The 30:30** 10 x 30secs sprint, 30secs jog
- **Interval 200m** 10 x 200m fast, 200m jog
- **Interval 300m** 6 x 300m fast, 100m walk in 60-90secs
- **Long repetitions**, *eg* 4-5 x 3mins fast, 3mins jog

Mental endurance for tennis

Tennis players need endurance: even though five-set matches are rare, players need to be able to play more than one match in a day, which involves several hours on court. On the other hand, tennis players get a lot of rests. A study of filmed tournament players revealed an exercise-to-recovery ratio of 1:2.5; this means that for every two minutes of movement they had five minutes standing or sitting. Even though some of the movement is very fast and demanding, few rallies last longer than 10 seconds, so the energy comes from anaerobic sources.

Because of the long recovery periods, 'endurance' for tennis players is as much mental as physical . The essential qualities are skill, judgement, agility, coordination and muscular strength.

Cardiovascular training

The mean heart rate for trained players in their 20s is 140-160 beats per minutes during singles competitions, indicating an overall intensity of 60-79% VO2max. However, heart rates can rise as high as 190-200 beats/min during long and fast rallies, while several authors have reported higher heart rates for servers than receivers – probably because of greater psychological stress – and in hot and humid climates. In terms of adaptation, well-trained tennis players have lower resting heart rates and lower blood pressures than untrained controls.

This tells us two things:
1. You need be fit to play tennis well;
2. Trained tennis players are a lot fitter than normal people.

For ageing players hoping to stay in the top class, a high level of fitness is even more essential because their playing skills have already been developed and they need to retain as high a VO2max as possible if they are to maintain their confidence and perform well.

Research shows that fitness cannot be achieved solely by match specific, on-court tennis training, and players are advised to follow additional conditioning programmes known to improve both aerobic and anaerobic performance. Training in the conditioning period will include a lot of work on arm, shoulder, back and abdominal strength. In the run-up to competition, regular work on speed and agility is vital, and players should include some interval regimes in their training.

For a sport like tennis, with long recovery periods, short distances are recommended, and the training should resemble that of a 400m or 800m runner, including such sessions as:

- **up the clock** 60m, 80m, 100m, 120m, 140m, 160m, then back in the same stages to 60m, walking back to the start after each fast run
- **short interval training** 2 sets of 6 x 200m fast run, with 1-2mins recovery after each fast 200 and an extra 3mins between sets
- **hill sprints** 6-10 x 40secs uphill fast, walking back

Of course, if you lack the requisite skills no amount of training will make you a good player. On the other hand, if a player is not in good condition, technique, coordination, concentration and tactics cannot be brought fully into play, as premature fatigue impairs virtually all tennis specific skills.

Squash and racquets training

Research has proved what we all know – that squash is a good exercise for fitness. All the above advice for tennis players applies equally to squash and racquets, whose speed and intensity make them even more demanding. The implications are that:

1. Cardiovascular training is even more important than it is for tennis because rallies may last as long as 60 seconds at a time, at a very fast pace;
2. The injury risk is greater for unfit players, and older players must take due care.

Interval training for other sports

Should older squash player or hockey players be using this type of endurance training in place of the more conventional schedule of steady runs?

Since the object of 'off-the-pitch' training is to improve a performer's fitness, interval training makes much better use of the time and is more effective for improving VO2max – *ie* aerobic fitness. In a session of 12 x 400m performed in, say, 75 seconds, with a 90 seconds recovery jog, the athlete will be training for 33 minutes and will cover 7,200m (4.5 miles), excluding the warm-up and warm-down. He will therefore cover over five miles in all; moreover, the improvement in fitness can be measured very precisely, particularly if a heart monitor is used.

Because most hard efforts are short, the interval work recommended for tennis players would also be useful.

The importance of mental strength

Mental strength will not improve your speed by a minute a mile, but if you are fighting out a battle with people of your own ability – or your own age group – it can make the decisive difference between winning and losing. A lot depends on your state of mind going into the event.

Taking part in Masters or age-group competition gives people a chance or reaching levels of achievement that were beyond them in previous years. An essential step in this situation is to make a realistic appraisal of your position. Success in endurance sports relies as much on training as on natural ability, and those who enjoyed success in their 20s, then took a long break have to be prepared to start at the bottom. On the other hand, those who persevere with club competition into their late 30s may find themselves propelled into international class at age 40. The chance of winning medals in international competitions can have a dramatic effect on your ambitions and performances.

The arousal curve

The model of the 'arousal curve' goes a long way towards explaining the psychology of performance. If you plot a graph with performance on the vertical axis and 'level of excitement or arousal' on the horizontal, the graph takes the form of an inverted U. When an athlete is only mildly interested in an event, the performance level is low; as he becomes more and more nervous and excited, so producing more adrenaline, the level of performance rises, but when he reaches a certain pitch of excitement it starts to spoil the performance. Phrases like 'nervous tension', 'over-anxiety' and 'too much pressure' are used to describe this point in the curve.

The arousal curve shows how over-anxiety can impair performance even more than under-arousal. Fortunately, though, both can be modified by suitable training techniques.

'The chance of winning medals in international competitions can have a dramatic effect on your ambitions and performances'

A low level of arousal may be due to a number of factors:

- overtraining or boring training
- over-confidence or lack of knowledge of the opposition
- illness or stress from some other source.

In the physiological sense, the poor performance can be explained by low levels of stress hormones – adrenaline in the blood and noradrenaline in the tissues. With little adrenaline being produced, the breakdown of glycogen is insufficient, so blood glucose levels fall. If the motor centres of the brain are not sufficiently aroused, the recruitment of muscle fibres may be below optimum; and with fewer fibres working, they will tire more easily.

Preparation techniques

The first thing an athlete or coach needs to do is to define the task in hand and focus on what is needed. The last few days before the event should be programmed so that small tasks are achieved and specific training routines performed, all designed to remind the athlete of the bigger challenge ahead. The more important the event, the longer it will have been on the calendar and the longer imprinted on the athlete's mind as 'the one that counts'.

Setting targets

Satisfaction lies in the difference between performance and expectation. George Gandy, the highly successful distance running coach at Loughborough University, asks his athletes to have 'gold, silver and bronze' goals. The gold is the highest they can possibly expect in their current condition and the bronze is the lowest performance that would satisfy them.

Depending on the event, goals may be defined as beating certain people, finishing in a certain position or delivering a measurable performance.

The important thing is to have a target so that you are always focused on how to reach it. If is no good, though, if that target is impossibly high.

Visualisation

This technique goes one stage further than merely focussing on the outcome. In the days leading up to the event, you run through the competition in your mind. Steve Backley, the world record-holder for the javelin and four-time European champion, would mentally rehearse his throws while lying in bed after an operation, imagining the acceleration of his run-up, the pattern of the last three strides and the mighty pull of his arm, sending the javelin up into the perfect flight. David

Hemery, Olympic champion over 400m hurdles, is a very strong believer in the value of visualisation as a way of programming body and mind for optimum performance.

Rehearsal

This technique, which reinforces visualisation, can be physical as well as mental. Of course, much of training is event specific, rehearsing the actions that will be used in competition. Jonny Wilkinson is known to practise his goal-kicking for hours, while golfers practise their driving and chipping. In running or cycling, you can practise particular situations, such as the tactical break or the final kick. Gary Player's remark on this subject has become famous: when someone said how lucky he was to have holed a shot out of a bunker, he said : 'The harder I practise, the luckier I get'.

Training to win

In his book *Psyching in sport* Dr Brent Rushall lists the attributes of successful athletes as follows:

- ability to concentrate throughout the training period
- ability to put more intensity and effort into competition than training
- confidence in the ability to perform up to expectation
- frequent mental rehearsal of the event
- having a detailed competitive strategy
- ability to adapt to changing situations
- ability to rise above small distractions
- ability to regain mental control in difficult situations.

Reducing anxiety

Returning to the arousal curve, you can see that the key to success lies in being able to control the excitement and handle the tension that surrounds a major event. The problem in focussing on one event for weeks or months is that fear of failure and worry about the opposition can loom so large as to inhibit performance. The winning athlete has the ability to relax, stay calm and not be over-awed by the situation.

Techniques which help this are:

- **Meditation** This can be done with yoga techniques, or simply by finding a quiet spot for a few minutes each day, breathing deeply and setting the mind free of its worries. You can practise muscular relaxation at the same time by tensing and relaxing each muscle group in turn, from the toes up to the neck and back down again.
- **Drills and habits** When competing in strange environments, it helps to have set routines for warming up before the event. By using the same routine that has worked in the past, you reinforce your confidence. This can be applied to eating and drinking as well, but not so rigidly that you are thrown by not getting your his usual food. The 'lucky mascot' technique, though much used, is not recommended.
- **Self-hypnosis** This is subtly different from concentration. The idea is to have a series of phrases or 'mantras' which, when repeated to yourself, have a calming and reinforcing effect. Good examples are:
  – 'All is going to be well'
  – 'This is going to be my day'
  – 'Little things don't matter'
  – 'Who is going to win? I am going to win'.
- **Talking it through** This is where the coach has a particular value, as someone who is knowledgeable but can keep things in perspective. Your coach might say to you: 'What is the worst thing that could happen? What would you do then?' He can then show you that, by concentrating on your own technique, you can shut out your worries about the crowd, the opposition or the media.

Summary of training recommendations

All the sports referred to in this chapter demand a wide range of physical skills as well as endurance and aerobic fitness. A pre-season programme needs to include training to improve leg power and agility as well as endurance, upper body strength and aerobic fitness.

The key points to take away are:

1. Analyse the demands of your sport. Maintaining endurance may be important, but so is retaining flexibility and mobility;
2. Assign time to each area depending on the facilities available to you. For example, leg power could be improved by weight training, plyometrics or hill running;
3. Start with conditioning, building endurance and cardiovascular fitness at a steady pace, at first on alternate days, then 5-6 days a week;
4. As soon as you can cope with 30 minutes of continuous exercise, start to introduce work at a faster tempo;
5. Introduce one training element at a time – *ie* don't start weight training and interval training in the same week;
6. Carry out training sessions that relate to your sport in intensity at least twice a week in the pre-competition phase;
7. Set a programme for no more than 13 weeks at a time, increasing the workload every two weeks until you reach your upper level;
8. During the competition season, retain one endurance training session per week;
9. Monitor your muscular strength and take corrective action when necessary;
10. Maintain flexibility and mobility by performing a regular set of stretching and loosening exercises at least three times a week.

References

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