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Interval Training

Introduction

The following refers specifically to middle and long distance running, but many of the general principles are applicable to other forms of athletic competition. Keep in mind at all times why you run. Perhaps it is something that generates fitness, provides a sense of achievement, or provides social interaction. You are most likely to get more out of running if it is part of your life, balanced by the other things you do.

Before commencing any program of demanding physical training, it is a good idea to have a comprehensive physical check up. This is particularly advisable if you have previously led a sedentary life and/or are in the masters age group. Tell your GP what your goals are and what you plan to do to achieve them. Have a blood test that includes iron levels and stores. This record will provide a base level against which subsequent regular checkups (perhaps annually) can be compared.

A program of demanding physical exercise of the type associated with interval training should only be undertaken by a fit and well person. It is advisable to improve cardiovascular fitness and “harden” the body through a program of running, slowly increasing the weekly frequency of runs, building distance gradually over time for around 12 months before starting interval training. Sharp pain, nausea or significantly degraded performance is a signal to stop physical effort, to determine the cause of the problem and the best means of eliminating that problem.

What is it?

Interval training consists of repetition runs over a specific distance, done in a set time, separated by recovery periods that are specified in terms of duration, distance, or both (i.e. it consists of alternating intervals of fast running and recovery). Training sessions will focus on specific race demands. It is a component of a balanced training program that will include recovery days and a range of other running activities, depending on the goals of the individual. A mix of interval training, a range of distances and types of runs (for example, hills, cross country) contribute to overall fitness and the capacity to engage in successful competitive running.

What does interval training do?

The physical side

The basic material that you have to work with, your body, is a function of your family genetic history and the environment that has formed it. Skeletal muscle makes up approximately 40% of body mass. The purpose of training is to:

- increase muscle strength without significantly increasing muscle bulk;
- strengthen connective tissue to enable it to cope with increased demand;
- improve the effectiveness of the energy systems that power the muscles;
- maximise the capacity of the body to get oxygenated blood to muscle fibres and remove substances that inhibit efficient muscle function;
- improve the capacity of the neural system to recruit muscle fibres in a manner that maximises running performance.

Muscular response to workload is very specific to the demands of that workload. The aim is to impose stress on the body that conditions it to provide an improved and coordinated response to future demands of the same or very similar type, i.e. to improve performance. This must be done without overstressing the body and causing muscle, connective tissue and/or skeletal injury. There will always be some muscle stiffness and soreness after hard training as muscle fibres are damaged and rebuilt. This is why recovery periods and a graded approach to training load are important. Recovery time is an integral part of training, not an option. Unrealistic personal expectations may lead to injuries that enforce long breaks from running and often this can cause a loss of motivation.

The mental side

Competing to the best of your physical ability requires a positive attitude towards training consistently and in a manner that places a level of demand on the body that is directly linked to your goals. It also requires that you develop (or improve) your control over the voice inside your head that is urging you to slow down when you engage in sustained strenuous activity. If you feel pain, nausea, light headedness or any other symptom associated with injury or illness you should certainly slow down or stop and determine the cause before continuing or withdrawing from the activity. We all seem to have a subconscious desire to reduce the things that cause discomfort and this can generate a feeling of fatigue even when the activity we are engaged in is at a level well below that

which may cause harmful tissue damage. If this is the cause of the urge to slow down you can develop strategies to overcome this urge. Thinking about what you are feeling during training, monitoring your body and reacting accordingly is just as important as the physical side of training.

Racing has its own mental demands. You have to deal with preparing for a race, interacting with other competitors before the start and during the race (for example, how do you respond if someone runs close behind you or passes when you would not have expected them to?), and analysing your performance after the race in a manner that builds confidence for the next race. Activities that improve your ability to react positively to these things can be incorporated in your training. There is no substitute to actually being in a race, but you can reduce the negative aspects of race stress by working through race scenarios in training.

The total picture

On the day, getting the best out of a training session or competing to the best of your ability involves appropriate preparation, having demanding, but achievable goals for the activity and a post activity routine that assists you to recover as efficiently as possible, ready for the next activity. Getting to a venue on time to warm up, being physically and mentally prepared, having the equipment you need, knowing the “rules” associated with the activity you are about to engage in, being able to deal with other athletes, coaches and officials, etc, are all things contribute to the success or otherwise of the outcome of an activity.

Why train?

There is little point in training unless you compete, particularly if the training is demanding. The performance targets you set for yourself at a particular time determine the nature and level of training you need to undertake. Progress towards these targets is a significant factor in providing the motivation to overcome the mental and physical barriers that you will face when things get hard. Does it ever get easy? No, not if you want to perform at your best. It takes sustained effort to improve and similar effort to maintain a high level of individual performance. Racing is itself a component of an overall training program. Each race should be seen as a learning experience in terms of the strategies you employ and in extending the physical and neural attributes you apply to your running.

A basic functional knowledge of the system of muscles, bones, connective tissue, cardiovascular system and the energy systems that are essential for movement helps you to understand how particular training sessions are linked to specific outcomes.

Muscle function

Skeletal muscle consists of bundles of muscle fibres attached to bone by connective tissue, activated by nerve fibres, with fine capillaries transporting blood to and from the muscle fibres. At the molecular level, muscles contract by moving long protein chains over each other, a process that requires a substance called Adenine Triphosphate (ATP).

There are three broad types of muscle fibres:

Type I, also called red, slow twitch or slow oxidative fibres. These fibres have a slow contraction velocity, have a high capacity to generate ATP by oxidative processes and are very resistant to fatigue.

Type IIA, also called fast twitch or fast oxidative fibres. These fibres are red, have a high contraction velocity, have a high capacity to generate ATP by oxidative processes and are resistant to fatigue.

Type IIB, also called white, fast twitch or fast glycolytic fibres. These fibres have a very fast contraction velocity, generate ATP by anaerobic processes and fatigue easily.

Fibre colour depends on the extent of capillarisation, that is, the density of blood supply vessels they have. Type I fibres are the most common in human muscles. These are the fibres that maintain sitting and standing posture. The proportion of each type of fibre that an individual has cannot be changed in a mature individual, although the structure and metabolic capacity of individual fibres can adapt specifically to training demands.

Each motor nerve ending attaches to a bundle of fibres of the same type. Type I slow twitch fibres are always recruited first, to meet demands for weak contraction. If a stronger contraction is needed, type IIA fibres are recruited to assist the type I fibres. Maximum contractions require the use of type IIB fibres. The fatigue resistant properties of type I fibres make them important for endurance activities. For most of our activities a combination of fibres types will be active at any one time with the demand of the activity determining the proportion of each type of fibre.

Fatigue does not depend solely on muscle fibres themselves, the nervous system is also a factor as is a subconscious function of the brain to regulate physical activity to a comfortable level.

Energy pathways

Some ATP is stored in muscle cells and is available for immediate use. It is converted in the muscle cells to Adenine Diphosphate (ADP) with the release of energy for muscle contraction. Stored ATP can provide energy for 1-2 seconds and can be replenished by the following three processes .

- **Anaerobic CP (alactic) system:** Creatine Phosphate (CP) is synthesised in the liver, pancreas and kidneys from amino acids derived from food. It is released into the blood and stored in muscle cells. CP is used to convert ADP to ATP, which can then be used to contract muscle fibres. There is usually enough CP in the muscles for approximately 6-8 seconds of maximum effort.

- **Anaerobic glycolytic (or lactic) system:** In the absence of oxygen, the breakdown of blood glucose and glycogen stored in the liver and muscle cells produces ATP from ADP, with the by-products being lactate and hydrogen ions. An accumulation of the by-products of this process progressively reduces muscle cell function and contributes to feelings of “burning in the legs” and fatigue . The process is a self-limiting one that supports 20-45 seconds of maximum activity, after which the body slows to a pace that can be sustained with the use of the aerobic system. Any activity that relies

predominantly on anaerobic lactic energy processes will feel physically and mentally demanding.

- **Aerobic oxidative system:** In the presence of sufficient oxygen, carbohydrates (glucose, and the glycogen form it takes when stored in muscles and the liver), fatty acids and proteins can be used to convert ADP to ATP. In the presence of oxygen, lactate from glycolytic processes can also be quickly used to generate ATP. Energy can be delivered by the aerobic system for long periods of time, depending on the amount of carbohydrate, fats and protein available. Fat metabolism requires more oxygen than carbohydrate metabolism, the latter being preferred by the body as fuel for high intensity exercise.

The three systems are not independent, but operate concurrently to different degrees. At any time, glycolytic muscle fibres will be producing lactate that oxidative fibres can use as fuel. Lactate will be shuffled around the body during periods of strenuous activity. The aerobic system allows for the regeneration of the other two systems. Lactate, creatine (and other substances in muscle cells) are moved by special proteins called transporters, across cell membranes, to places in the cells where they are needed. Transportation of substances is a process that can also be influenced by training.

The “powerhouses” of muscle cells are small structures called mitochondria. In the mitochondria, complex chemical reaction cycles take place that generate ATP. Clearly, the more mitochondria you have in your muscle cells, the more energy you have to power those muscles. Training that leads to a high aerobic demand will result in higher muscle mitochondria densities.

Muscle cell energy systems can be summarised in the following table:

| <i>Duration (secs)</i> | <i>Classification</i> | <i>Energy sources</i> |
|------------------------|-----------------------|------------------------------|
| 1-2 | Anaerobic | Muscle ATP |
| 2-10 | Anaerobic | ATP+CP |
| 10-45 | Anaerobic | ATP+CP+glycogen |
| 45-120 | Anaerobic glycolytic | Glycogen/glucose |
| 120-140 | Aerobic + anaerobic | Glycogen/glucose+lactate |
| 140+ | Aerobic | Glycogen/glucose+fatty acids |

[The duration times given are for maximum effort, are approximate and depend on the individual.]

The above is a simplified description of what goes on to energise muscle cells. There are many other processes, some not well understood, involving a large number of molecules, many of them complex, which are essential to muscle function. Training should target development of each of the above energy systems, capillarisation of blood, capacity of the heart and lungs and efficiency of the motor nerve system to recruit fibres to meet demand. Having strong muscle fibres only helps you to run faster if the brain recruits those fibres in the best pattern to support that action.

Challenging each energy system

The following table indicates the approximate contribution of energy systems for various race distances. The energy requirements of the race distance you want to focus on

provide a guide to the type of interval training that will be most effective for you. This doesn't mean that you cannot run across a range of events, but this will involve compromises as it is impossible to maximise outcomes for sprints, middle distance and long distance - the requirements are simply too different.

| Event | % energy system contribution (approx) | | |
|--------------|---------------------------------------|--------|---------|
| | Anaerobic | | Aerobic |
| | alactic | lactic | |
| 100m | 70 | 22 | 8 |
| 200m | 40 | 45 | 15 |
| 400m | 10 | 60 | 30 |
| 800m | 5 | 40 | 55 |
| 1500m | 2 | 23 | 75 |
| 3000m | <1 | 12 | 88 |
| 5000m | <1 | 7 | 93 |
| 10000m | <1 | 3 | 97 |
| 1/2 marathon | <1 | <1 | 99 |

(Data drawn from Martin & Coe, 1997, "Better Training for Distance Runners", Human Kinetics, p 185)

Most well designed interval training sessions will place demand on each energy system to some degree. The proportional demand depends on the nature of the session. There are many different ways to challenge each of the energy systems so there is no "magic" session that is better than any other. Adopting the training program of an elite runner probably will not work for you unless you have the same attributes as that runner. Think about what you want to achieve and look for a balanced set of sessions that contribute to that goal.

Short, fast intervals of 6-15 seconds duration will challenge the anaerobic ATP-CP system system. It takes at least 3 minutes for CP synthesis to replace that which is used hence recovery times should be at least 3 minutes.

To challenge the anaerobic glycolytic system, the ATP-CP system must first be exhausted. High intensity sessions that result in accumulating lactate and hydrogen ions are both mentally and physically demanding and require a progressive approach. The aims are to increase the running speed at which lactate accumulation begins to occur, to train the body to reduce (or buffer) the accompanying cell acidity, to shuffle lactate around the body and reprocess it more efficiently and to improve the mental toughness to maintain speed at high levels of anaerobic lactic output. Repetitions run at around 95% intensity for 40-120 seconds (with demand for lactic tolerance increasing towards the end of each repetition) with relatively long recovery periods provide one way to challenge the anaerobic glycolytic system. Another approach is to run repetitions of 200-300m at around 85% effort with short, recovery periods of the same or lesser duration than the repetition (with demand for lactic tolerance accumulating through the session).

The aerobic system can be developed through both interval and distance running. For example, continuous running at around 70% of maximum heart rate (or 70% of maximum speed) for 45-60 minutes improves maximum oxygen uptake and blood capillarisation; trains the body to utilise glucose, fatty acids and proteins as fuels, and; improves the capacity to metabolise the lactate that is produced. It provides a base from which aerobic speed can be developed and also helps to develop the mental discipline and concentration needed for distance running.

Running longer repetitions at 3k–5k race pace with equivalent recovery times will also challenge the aerobic system, as will the type of sessions outlined below.

VO₂max, and vVO₂max

In response to increased physical demand, the autonomous nervous system increases heart and breathing rates. A point is eventually reached where an increase in workload cannot be matched with a rise in oxygen consumption and therefore, maximum oxygen uptake is reached. VO₂max is the maximum possible rate at which your body uses oxygen, usually expressed in mls per kg of body weight per minute (ml/kg/min). If two athletes are running at the same speed, but one is operating at a lower percentage of VO₂max, that person is said to have the better running economy of the two. VO₂max can be improved by high intensity intermittent training such as 100% effort for periods of around 20 seconds with recovery periods starting at around 3 minutes and decreasing over a period of time. For a fit athlete, 3 and 5km races can also increase VO₂max.

vVO₂max is the lowest running speed that produces. The French sports scientist Professor Veronique Billat has developed a vVO₂max session, which consists of a repeated cycle of:

- 30 seconds at 100% of vVO₂max
- 30 seconds recovery at 50% of vVO₂max

for as long as the 30 seconds at 100% vVO₂max can be sustained - essentially an anaerobic training session. The 100% and 50% efforts are important if gains are to be achieved.

vVO₂max can be estimated by measuring the maximum distance travelled in 6 minutes and dividing this by 360 to get speed in m/sec. For training purposes it is more convenient to convert this to seconds per 400m. It is equivalent to the speed you should be able to maintain for a 3km race.

Technique, economy and neuromuscular training

Running drills such as high knee lifts, hopping, skipping and other “quick feet” exercises can assist in developing an efficient neuromuscular response to demands on the body. Some of these exercises provide dynamic stretching, others have a plyometric effect where a strong muscle contraction quickly follows a muscle stretching action. When a muscle is stretched, elastic energy is stored in connective tissue and improving the ability to utilise this stored energy for movement (instead of it being dissipated as heat) is always important, but becomes more important with increasing age. The aim is to optimise coordination, to concentrate effort on forward propulsion by reducing energy loss to non-essential muscle use and minimising wasted time. For example, reducing the time each foot contacts the ground by using a more explosive footstrike technique (while maintaining stride length) leads to a higher strike rate and hence greater speed. Running economy is improved by coordinated minimal recruitment of appropriate groups of muscle fibres to achieve the best speed possible for a given percentage of VO₂max. Training and race experience contribute to the development of confidence and the mental toughness to be able to maintain or increase pace when it would be easier to slow down, to reduce effort to a ‘comfort zone’.

Decreased muscle mass, a decrease in the elasticity of connective tissue and a decrease in maximum heart rate are some of the consequences of increasing age. These, and other factors, lead to decreased stride length, an increase in the time that each foot is on the ground, decreased back lift of the feet and hence loss of speed. Slowing with age is inevitable, but the rate at which slowing occurs can be influenced by training that recognises aging factors and aims to reduce their impact on performance.

Generally speaking, if you want to slow the rate of degradation, you have to maintain high intensity training. If all you do is long slow running, there is little or no demand on fast twitch muscle fibres so the nerve pathways to these fibres gradually decay and the fibres atrophy. Loss of power muscle fibres contributes to the slowing factors outlined above. The old adage “use it or lose it” applies all too well to running fast.

Putting it all together

A masters athlete who wants to compete all year round requires a combination of training sessions, with appropriate recovery periods between those sessions. Some sessions will target more than one energy system, with different combinations of intervals to motivate training and avoid ‘locking in’ to a particular distance. Increased demand can be achieved through faster intervals and/or reduced interval recovery periods, depending on the aim of the session.

Research has shown that effective anaerobic training is an essential component of good distance running. It is not enough to focus on the aerobic system. Maximum sprint speed, speed and force of muscle contraction, neuromuscular characteristics, stride rate and length, footstrike time, and the components of anaerobic lactic tolerance all contribute to good distance running performance. All of these factors respond to training. Distance

races rely predominantly on the aerobic system, but training that increases $\dot{V}O_2\text{max}$ assists an athlete to run distance races aerobically at a faster speed. Training the anaerobic system provides the capacity to surge during a race and to increase pace at the finish.

Effective training requires knowing what a particular effort intensity means for you. Repetitions should be run at race paces so that you become good at pace judgement. Training the neuromuscular system to lock in to specific race paces also assists you to run more comfortably at those paces in a race. Monitoring your body as you run trains you to avoid wasting energy through such things as clenched fists, hunched shoulders, etc.

Know what you want to achieve and set realistic training and race targets that are consistent with the physical and mental demands that you are both willing and able to meet to attain your goals. Achieving goals boosts confidence and helps to provide the motivation needed to continue with demanding training – just because something is difficult doesn't mean that it has to be unpleasant.