The Nine Key Elements of Fitness

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The Nine Key Elements of Fitness

One of the misconceptions in the sports world is that a sportsperson gets in shape by just playing or taking part in his/her chosen sport. If a stationary level of performance, consistent ability in executing a few limited skills, is your goal then engaging only in your sport will keep you there. However, if you want the utmost efficiency, consistent improvement, and balanced abilities sportsmen and women must participate in year round conditioning programs. The bottom line in sports conditioning and fitness training is stress. Not mental stress, but adaptive body stress. Sportsmen and women must put their bodies under a certain amount of stress to increase physical capabilities.

Exercise scientists have identified that fitness comprises of nine key elements. The following lists each of the nine elements and an example of how they are used:

- **Strength** – the extent to which muscles can exert force by contracting against resistance (holding or restraining an object or person)
- **Power** – the ability to exert maximum muscular contraction instantly in an explosive burst of movements (jumping or sprint starting)
- **Agility** – the ability to perform a series of explosive power movements in rapid succession in opposing directions (zigzag running or cutting movements)
- **Balance** – the ability to control the body's position, either stationary (*eg* a handstand) or while moving (*eg* a gymnastics routine)
- **Flexibility** – the ability to achieve an extended range of motion without being impeded by excess tissue, *ie* fat or muscle (Executing a leg split)
- **Local Muscle Endurance** – a single muscle's ability to perform sustained work (rowing or cycling)
- **Cardiovascular Endurance** – the heart's ability to deliver blood to working muscles and their ability to use it (running long distances)
- **Strength Endurance** – a muscle's ability to perform a maximum contracture time after time (continuous explosive rebounding through an entire basketball game)
- **Co-ordination** – the ability to integrate the above listed components so that effective movements are achieved.

Of all the nine key elements of fitness cardiac respiratory qualities are the most important to develop as they enhance all the other components of the conditioning equation.

As a long-time UK Athletics coach, I have always been aware that advice at this level has been expensive and often difficult to obtain. This workbook solves the problems of cost and inconvenience in obtaining expert coaching guidance.

On the following pages you will find evidence-based advice based on £ millions worth of trials conducted by dedicated sports scientists, with comprehensive, science based workouts designed to enhance your performance for your sport or event.

Please let me know how you get on!

Best wishes

Brian Mackenzie
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Module 1

Strength

Strength

The nature of strength is always difficult to define. The strong runner, the strong shot-putter and the strong jumper clearly have little in common and yet we consistently group strength attributes together as if we are looking for the same result for each event. Strength is a generic term used to describe many dissimilar abilities. Examples of 'strengths' include the following:

- **Strength endurance** – the ability to move a light resistance for an extended period of time
- **Absolute dynamic strength** – the maximum force that a muscle can generate and apply to create movement
- **Absolute static strength** – the maximum force that a muscle can generate and apply without producing movement
- **Reactive strength** – the maximum force that muscles can apply in response to a force in the opposite direction
- **Power** – which most people confuse with 'strength', but is actually the absolute dynamic strength multiplied by the speed it can be applied.

From these it is clear that different events/sports need different 'strengths', and different 'strengths' need different training methods.

Overview of the articles in this section

- Raphael Brandon in his article 'Fish out of water: the land-lubbers' strength program for swim competition' provides a selection of land based weight training exercises specific to swimmers
- Walt Reynolds explains the four basic types of strength training for runners, identifies a strength program for runners and how to pinpoint

your weaknesses in his article 'If you want to benefit from strength training, you must identify your weaknesses and work on them'
- Raphael Brandon in his article 'Strength training is vital for women, but the program depends on their event, not their sex' explains how to devise a strength training program for female athletes
- Brian Mackenzie provides an example strength test that can be used to monitor upper body strength in his article 'The Press-ups Test'.

The articles in this section are applicable to most sports

Fish out of water: the land-lubbers' strength program for swim competition

To optimise strength and power, competitive swimmers need to supplement their pool training with land training in the gym. For best effect, swimmers need to follow a program of exercises that replicate their actions in the water as closely as possible.

Strength and conditioning experts around the world all agree that, for time spent in the gym to have a positive impact on your sports performance, you must ensure the exercises you perform, and the way you perform them, are related to your sporting movements in competition. For example, Barbell Squats involve ankle, knee and hip extensions in a vertical plane which are directly related to the mechanics of a vertical jump; thus the squat is a useful exercise for developing jump performance.

If we perform a basic analysis of the mechanics of the front crawl stroke, the main actions that produce forward propulsion through the water are:
- the 'arm pull down' through the water, which propels the swimmer forward
- the 'leg kick', which alternates hip flexion and extension of the legs.

In addition, competitive swimming involves:
- the 'dive start and push off turn', which involves dynamic ankle, knee and hip extension.

When designing your strength program, you should focus mainly on exercises related to these movements. Other exercises may use the same muscles as those involved in swimming, but only exercises which use the right muscles in a related mechanical movement will provide optimum training benefit.

A limitation of land training with weights for swimming is that the type of resistance you encounter when moving in the water is different from the resistance occurring when you move a weight through the air. In the water, the faster you pull or kick the greater the resistance applied back by the water; on land, a given weight requires a constant force to move it, regardless of the speed of movement.

Hydraulic-type resistance equipment that mimics aquatic resistance is expensive and not widely available. The best compromise when using regular equipment is to try to mimic the speed and nature of the swimming stroke. To this end, you should aim to perform the strength exercises with a smooth and constant force and select weights which allow the movement to be performed at a swimming-related speed. For example, the leg-kicking motion during front crawl is quite fast, so hip flexion and extension exercises which can be performed at a good speed would be best.

The following exercises are related to the mechanics of the front crawl stroke. For each component, the relevant exercises are described and their mechanical relationship to the stroke explained.

Arm pull down exercises

1. Cable rotational front and back pulls

Front pull. This is the mechanical equivalent to the pulling-through-the-water action in front crawl, as the hand comes diagonally across the body as it pulls down. For this exercise you need a high pulley machine with a simple handle grip.

Kneel down on one knee to the side of the machine. Take the hand nearest the pulley and grasp the handle with the hand high and slightly out to your side. Before you start the exercise make sure your back is straight, your shoulders are wide and your chin is tucked in. Pull the handle down and lower your arm across your body in a rotational movement until your hand is next to the opposite hip. Smoothly return the bar to the start position and continue performing sets of 5 to 8 repetitions for maximum strength or 12 to 15 repetitions for strength endurance. Try to keep your posture solid throughout the movement. Maintain a slight bend in the elbow as you pull, but focus your effort on the shoulder muscles only.

Rear pulls. This exercise involves the opposite movement to the front pull and is useful for promoting a balanced strength about the shoulder joint. Specifically, the front pull trains the internal rotator cuff muscles and the rear pull trains the external muscles. To avoid shoulder injuries a balanced rotator cuff strength is important. For this exercise you need a low pulley machine with the simple handle grip.

Stand to the side of the machine and grasp the handle with the opposite hand. Make sure your back is straight, your shoulders wide and your chin tucked in. Start with your hand by the inside hip and fix a slight bend in the elbow. Pull the handle up and away from your body, rotating the arm up and out. Finish with the handle high and out to the side, with the palm of the hand facing forwards. Smoothly return the handle back and across to the opposite hip and continue. Again go for sets of 5 to 8 repetitions for maximum strength or 12 to 15 repetitions for strength endurance.

Keeping your posture solid during this exercise is quite difficult, as it is tempting to use your trunk muscles to help the rotation movement. However, you can train your core stability skills by keeping your navel pulled into your spine and relaxing your upper body so there are no additional movements apart from the arm raise and rotation.

In combination, the front and rear diagonal pulls train almost every muscle in the shoulder joint and shoulder girdle. This makes them very useful exercises for any sport.

2. Medicine ball single arm overhead throw

This exercise develops the power of the latissimus and pectoral muscles in a functional manner for swimmers, involving a movement similar to the front crawl stroke. The aim of the throw is to improve the rate of force development in the shoulder by accelerating the arm hard to throw the ball. For this exercise you need a partner and 2 to 4kg ball. The small rubber ones are best as they can be held in one hand.

Because the ball is quite heavy for one hand you will not be able to throw it far or move the arm very fast. This makes it ideal for swimming as the pull stroke is not that fast. The training effect comes from your attempts to accelerate the arm movement as fast as you can, thereby improving the power of the pull.

Lie on your back on the floor, with knees bent slightly so your lower back is comfortable. Grasp the ball in one hand with your arm up and behind your head, slightly bent at the elbow. Vigorously pull the arm up and down across your body, throwing the ball over the opposite knee. Get your partner to return the ball, and perform sets of 8 to 12 repetitions with each arm in turn.

Do not lift your head or pull up from the stomach as you throw. Focus on producing the power from the shoulder and pulling across the body as you do in front crawl.

3. Swiss ball body pulls

This is a ‘closed kinetic chain’ movement, where the moving limbs remain in contact with a fixed object – in this case the hands with the floor. Such movements are thought to be particularly functional for sports performance, so offering greater training benefits.

This exercise is performed in a horizontal prone position, with the arms pulling down under the body, matching the position and action of a swimmer in the pool. Position yourself face down, with your lower legs on the Swiss ball and your hands on the floor supporting your weight, body parallel to the floor. This is the equivalent of a press-up position with your feet up. Slowly roll the ball up your legs while your arms extend out in front of you until you achieve a stretched position, with a straight line through your arms, shoulders, back, hips and legs. At this point your body will make a shallow angle with the floor and the ball will be positioned on your thighs. Then, keeping this perfect alignment of your body, push down through your hands into the floor and pull yourself back to the press-up position. The ball should roll back down your legs as you do this. Perform sets of 8 to 12 repetitions.

The difficult part of the exercise is the pull back up. At this point you must use your stomach muscles to support your spine and focus on using a strong pull of the shoulder muscles to raise your body back to the parallel position. This exercise is not easy, but it is very beneficial for many sports, helping to develop core and shoulder strength.

Leg kick exercises

Hip extension and flexion kick

These exercises mimic the upwards and downwards phases of the swimmer's kick action, where the glutes and hamstrings extend and the hip flexors flex the leg at the hip. For these exercises you need a low pulley machine with an ankle strap attachment. Each leg is worked independently to increase the specificity for swimming, and the weights used should be relatively light so you can kick with good speed, as in the pool.

Hip extension. Stand facing the low pulley machine, with the ankle strap attached to one leg. Lift this leg off the floor, taking up the slack of the cable, and place your balance solidly on the other leg. Hold onto the machine's frame with your hands to stabilise your upper body and check that your back is straight, with shoulders relaxed.

Pull the cable back dynamically by extending the leg backwards until you feel you need to lean forwards, then bring it back in a controlled manner to the start position, retaining good posture. Continue pulling the leg back, focusing on the gluteals and hamstrings to kick back powerfully.

Hip flexion. Stand with your back to the low pulley machine, with the ankle strap attached to one leg. Lift this leg off the floor, taking up the slack of the cable, and place your balance solidly on the other leg. Use a stick to support yourself, and check that your back is straight with your shoulders relaxed.

Pull the cable dynamically by kicking the leg forwards. Pull the weight, using your hip flexor muscles at the top and front of the thigh, until your leg reaches an angle of about 30° or you start to lean back. Smoothly return your leg to the start position, retaining good posture, and continue.

Perform sets of 10 repetitions at a fast speed and build up to sets of 20 or 30 repetitions for power endurance of this movement.

'Dive start and push-off turn' exercise

Barbell squat jumps

This exercise involves dynamic extension of the ankle, knee and hip joints and trains the calf, quadriceps and gluteal muscles to improve vertical jump performance. The vertical jump is mechanically related to the dive start and push-off turns involved in swimming: with the dive or turn, the ankle, knee and hip extension propels you forwards in the horizontal plane, while with the jump the leg extension propels you upwards in the vertical plane. Essentially, it is the same movement rotated by 90°.

The point of using a barbell to add weight to the squat is to help you to generate peak power. If you perform the jump squat with body weight only, the jump will be very fast and high. With the addition of a moderate weight (about 30 to 40% of the 1 repetition max weight for the squat exercise), the jump will not be as high or fast, but the muscular power required to leave the ground will be maximal. This is based on the knowledge that peak power is achieved when the force used is about one third of the maximum force for that movement. Again, your goal is to attempt to achieve the fastest extension of the legs to maximise power production and training benefit. If you use 30 to 40% of 1RM weight, I recommend 3 to 5 sets of 5 repetitions.

Stand with the barbell across the back of your shoulders. Squat down, bending at the hips and knee, making sure the weight goes down through the back half of your foot. When you reach the half squat position, drive up dynamically rapidly extending your legs so that you leave the floor briefly. Absorb the landing with soft knees and then go smoothly into the squat again. Continue for 5 repetitions.

The bottom line

In summary:

- Strength and power training is essential for elite swimming performance
- To optimise the benefit of land-based training, you must select exercises with mechanical relevance to the swimming action, particularly those movements which propel the swimmer through the water, such as the arm pull and leg kick

- As the resistance in the water is different from the resistance provided by weight equipment on land, unless you have special hydraulic equipment, you must also focus on mimicking the speed and smooth movement of the swimming stroke when performing land-based exercises
- Various exercises for the arm pull, leg kick, dive and turn movements are suggested, all with a good functional relationship to the swimming action. While this is not a definitive or exhaustive selection of exercises, especially as it focuses solely on front crawl, it involves highly specific swimming movements in terms of mechanics, positions and speed. When you design strength programs for swimming performance or any other sport, be sure to think about each exercise in terms of its relevance to performance.

Raphael Brandon

If you want to benefit from strength training, you must identify your weaknesses and work on them

Most runners think that strength training is something carried out in a weight room or gym utilising various pieces of equipment (barbells, dumbbells, weight machines, etc.). However, the truth is that strength training is any physical activity that emphasises the application of resistance to the muscular system. For runners, these activities include conventional exercises (presses, squats, pull-ups, etc.), running-specific strength exercises such as step-ups and one-leg squats, plyometric or 'jump' training, calisthenics, injury-preventing gymnastic exercises (walking on toes or heels), and throwing, twisting, and swinging activities with a medicine ball.

Are these activities really beneficial for runners?

Scientific research strongly suggests that conventional strength workouts can decrease the risk of injury in endurance athletes. This can promote higher performances by fostering more consistent training. In addition, work carried out by celebrated Finnish researcher Paavo Komi indicates that strength programs can heighten maximal running speed, and more recent studies indicate that strength training can enhance running economy by about 3%, enough to shave about a minute from 10km times. We know also that plyometric training can help strong runners become faster, *eg* utilise the strength in their legs more quickly. Finally, strength routines help some runners add a few muscular contours to their bodies and emerge from their 'skinny-stick' physiques.

Many runners fear that strength training has a 'down side' – large, undesirable gains in muscle mass, which create more 'dead weight' to be lugged around during running. This fear is based more on myth than reality. The truth is that significant increases in muscle mass require specific training methods and a huge commitment of time and energy – far more than most runners are able to spend on strength training alone.

A program to develop leg strength

Of course, the way to benefit from strength activities is to increase their difficulty and specificity over time. For example, you could start developing more leg strength for running by doing basic two-legged squats – with only body weight for resistance – for two to three weeks. Then, you could progressively increase the difficulty and specificity of the exercises in the following manner: during weeks 4 to 6, you could carry out two-legged squats with greater resistance (while holding a barbell or dumbbells). For weeks 6 to 8, you could complete one-leg squats with light to moderate resistance (doing one-leg squats is more specific to running than two-legged squats, since full weight is on only one foot at a time, as it is during running). During weeks 9 to 12, you could move on to uphill runs while wearing a weighted vest to strengthen the 'push-off' phase of your running strides. During weeks 11 to 13 (overlapping the weight-vest period), you could add in two-legged forward hopping, to enhance power production while landing/rebounding during running. For weeks 13 to 15, you could move on to one-leg forward hops (since you would be landing on only one foot at a time, the specificity would increase and the intensity (difficulty) would double). During weeks 15 to 17, you could emphasise downhill running to learn to control and enhance the rebound phase of foot-strike.

A simple program like this will add some strength and power to your legs, but a key problem is that there are nearly an infinite number of strength exercises and almost as many workout programs. How do you select the exercises and program which are perfect for you? How do you coordinate your strength program with your running routine?

Pinpointing your weak links

Those are difficult questions to answer, because the truth is that there is not a single set of strength exercises which is best for all runners; instead, there are a few best strength-training exercises for YOU. That is because – if you are like most runners – you have unique strengths and weaknesses. For each of your weaknesses, there are a handful of strength-training exercises that will make you stronger. Your job is to identify your weaknesses and strengthen them.

But how do you pinpoint your weak links? Certainly, if you are recurrently injured in one part of your body, that area is unnecessarily weak and needs to be bolstered. Or, if you find that you have decent foot speed but you are always breaking down with a variety of different injuries, then you may need to develop basic overall strength (and/or flexibility). On the other hand, if you are seldom injured and have good endurance but little speed, your need is for a resistance program which will 'teach' those strong muscles of yours to function more quickly (*eg* your program needs to emphasise power training). Sometimes, working with a knowledgeable coach or trainer will help you identify things you should stress during strength training.

And it helps to know that there are really just four basic types of strength training for runners, each of which can assist you in accomplishing a specific goal. The four types are described below:

1. General strength and conditioning exercises

These activities include many of the conventional weight-training exercises such as presses, squats, pull-ups, push-ups, abdominal crunches, bar dips, various rowing movements, and the like. Also included in this category are some of the less conventional exercises like medicine ball throws and twists and various activities for the 'core' muscles (abdominals and low back). These conventional exercises provide 'generalised' strength – strength throughout your body to protect your muscles and connective tissues from the repetitive stresses and impacts of running.

2. Running-specific strength training

This category includes exercises that more closely imitate the biomechanics and motor patterns required for running. The exercises include step-ups, speed squats, one-leg squats, jumping lunges, hill running, weighted runs (while wearing a weight vest) and resistance runs (with rubber tubing, a parachute, or a weight sledge providing the resistance). This specific type of strength training, less familiar than general strength training to many athletes, is becoming increasingly popular in the sports-training community because it provides 'specific strength' – more strength to carry out the actual movements needed in a particular sport. When you carry out running-specific strength training, you get stronger while running – not just while seated at a weight machine.

3. Reactive or speed-strength training

This type of training, often referred to as plyometrics, includes various types of hopping, bounding, and jumping exercises which teach your muscles to generate more force and generate the force more quickly. The goal, of course, is to develop more powerful 'push-offs' when you are running. Reactive training fosters a high degree of strength in the muscles, tendons, ligaments, and bones, since the impact forces are usually higher than they are during regular running workouts. Reactive training also stretches muscles, tendons, and ligaments vigorously, promoting greater elasticity and efficiency of movement. A key point to remember, though, is that reactive training cannot simply be plopped into your training routine without preparation; it is built on a foundation of general and running-specific strength training and must start slowly with low-level hopping and jumping. Otherwise, the forces generated during reactive training will create injured – not more powerful – parts of your body.

4. Preventive gymnastics exercises

This is no doubt a new area of training for you. When most Americans hear the term gymnastics, they think of gymnasts performing dangerous flips, twists, and stunts on the balance beam, parallel bars, or rings. In the European training community, however, the term gymnastics is synonymous with strengthening, rehabilitative, or restorative exercise or therapy. For runners, the function of preventive gymnastics is to strengthen the feet and lower parts of the legs in order to minimise the risk of injury in those areas. Gymnastics exercises differ from general and running-specific strength exercises in that their effects are more localised, their intensity is lower, and they are actually carried out more frequently than other forms of strength training. A number of gymnastics exercises, including walking on toes and heels, skipping on toes forward and backward, toe pulls, zigzag bounding on the toes, and running barefooted on sand, grass, or hills, can be carried out nearly every training day, often as part of your warm-up or cool-down.

Coordinate your training

Obviously, it is not enough to throw a few exercises together, slap some weight on a bar, and start lifting. A comprehensive, optimal strength programme will include work in each of the four categories described above, with an emphasis on your weak points. At the same time, your strength program needs to be coordinated with all of the other training that you do, and it must complement – not detract from – your running. After all, you are training to run better, not lift weights better.

For example, let us say that you plan to start serious strength training this March and that your most important races of the year will take place in September. In March and April, you can simply focus on general strength and conditioning exercises. In mid-April you would begin to add in some running-specific strength training, which would continue through mid-June. In early June, you would start up your reactive (speed-strength) training as the racing season gets into full swing, and in mid June you would make your running-specific work more difficult. This combination of running-specific and speed-strength work would continue through the end of July. In August, you would 'fine-tune' your strength training, bolster any remaining weak links, and continue to focus on the speed-strength work which will help 'sharpen' you for your key September races. Throughout this period, from March to September, you would carry out your injury-preventing 'gymnastic' exercises.

Walt Reynolds

Strength training is vital for women, but the program depends on their event, not their sex

A survey of US schoolchildren in 1985 comprising various motor tests showed that the average 18-year-old girl could perform only one pull-up. It also showed that the sit-up-in-one-minute score peaked for girls at 14 years, with abdominal strength endurance declining from then on. The standing long jump test also indicated that on average girls peak at 14 years. In comparison, the average boy scored significantly higher on the test and improved until 18 years old.

These statistics merely illustrate what everyone knows, that women naturally develop less strength than men. The differences can be explained by the fact that at puberty boys have increased testosterone levels which promotes muscle development and bone growth over the next few years, whereas girls have increased oestrogen which promotes quite fast pelvic bone growth and fat storage around the hips and thighs.

After puberty, boys' relative fat mass decreases from 16 to 13%, while girls' relative fat mass increases from 18 to 26%. Indeed, research has shown that most of the differences in strength between men and women can be explained in terms of differences in lean body mass and muscle and fat distribution. Women have smaller arm girth and greater arm skinfold thickness than men, similar leg girth but greater leg skinfold thickness than men. This different distribution of extra fat and smaller muscle mass accounts for much of the disparity in strength between the sexes, women being about 66 to 75% as strong in the legs and 50 to 60% as strong in the arms.

Nevertheless, research has shown that normalising for lean body mass, which takes out the overall differences in muscle and fat, muscle pound to muscle pound women are similar in strength to men.

Can women respond to strength-training?

In the past, it was believed that strength training was unsuitable for women because they were 'incapable' of improving their strength. But more recent research has put paid to this theory. Professor Jack Wilmore from the University of Texas showed that after 10-week training program women showed a 29% improvement on the bench press and 30% improvement on the leg press, compared to a 17% and 26% improvement from men. However, while the men showed hypertrophy (enlargement) in the leg and arm muscles, the women did not. Wilmore hypothesised that the reason for the increased strength in women must be due to an increased ability to recruit muscle fibres and coordinate the movements. Later research has been equivocal – some has shown that women can increase muscle mass significantly, some has not. The tentative conclusion must be that in general most women find it more difficult to gain muscle mass.

Recently an official summary of all the research regarding strength training for women was presented in the US by the Women's Committee of the National Strength and Conditioning Association. They reported that:

1. Women improve fitness, athletic performance and reduce injuries through strength training, just as men do
2. Physiological responses of males and females to the use of weight training and resistance exercise are similar
3. Women should train for strength using the same exercises and techniques as men
4. There is no significant difference between the sexes in the ability to generate force per unit of cross-sectional muscle. Men display greater absolute strength than women largely because they have a greater body size and higher lean-body-mass-to-fat ratio
5. Women do experience muscle hypertrophy in response to resistance exercise, but the absolute degree is smaller than in men.

The conclusion to be drawn is that women are equally as strength-trainable as men. If female athletes want to achieve elite performances they must ensure that comprehensive strength training is fully covered in their training schedules. Competitions, unlike laboratory research, do not compensate for lean body mass. It is the fastest who wins, and that is the end of it. If you want to be that winner, you have to optimise your strength. In my opinion, that is a training priority.

What sort of training?

That being said, the next question is, what is the best form of strength training for women? The answer is not a matter of gender but more a matter of the particular requirements of the athlete's event, being the same for both men and women. Looked at from this point of view, any athlete must improve her (or his) strength if their profile is less than the strength demands of their event.

To devise the best strength program based on the event's requirements, we have to analyse the event in terms of muscle use, the type of contractions each muscle uses, the biomechanics of the movement and whether maximum strength or strength endurance is the goal. This kind of 'needs analysis' should govern the design of any strength program. As an illustration of such an analysis, let us look at running the 10km.

In the 10km event, the major leg muscles all work dynamically, such as the quadriceps, the hamstrings, gluteus maximus, hip flexors, calf and dorsi flexors. All these muscles are active at some point during the gait cycle and so it makes sense to strengthen them. However, they must all be strengthened in the right way to maximise 10km performance and injury prevention.

In 10km running 97% of the energy for muscle contractions comes from aerobic metabolism. Thus the predominant muscle-fibre units recruited at

10km pace will be the aerobic type I and IIa units. The more anaerobic type IIa and IIb units may only be recruited towards the end of the race as the muscles tire and glycogen is depleted. (type IIa fibre units can utilise both aerobic and anaerobic metabolism.)

For this reason, the 10km strength program must have a strength endurance emphasis which targets mainly the type I and type IIa fibre units. It has been shown that strength athletes who perform a few sets of a few repetitions of very heavy weights, *eg* 4 sets of 5 reps, have selective hypertrophy in the type IIb fibres, which would not necessarily benefit the 10km runner, whereas bodybuilders who perform higher volumes of lighter weights, *eg* 6 sets of 12 reps, show hypertrophy in the whole range of muscle fibres.

Although 10km athletes do not want to start bodybuilding, it could be argued that for the leg muscles a strength endurance training program of high repetitions and lighter weights would be the most suitable for a 10km athlete since the type I and IIa fibres will be targeted effectively. To improve strength endurance, 3 to 5 sets of 12 to 20 repetitions with 45 second rest periods are recommended.

The choice of leg exercises must reflect the biomechanics involved in the running movement. For example, since most thigh muscle activity occurs when one foot is in contact with the ground, single-legged exercises with the foot in contact with the ground or equipment will be most relevant. Single-legged leg press, lunges or one-legged squats are all exercises of this nature which target the muscles in the thigh and bum areas. The range of movement of the joints is also relevant.

For example, as the foot strikes the ground, the knee joint is slightly bent (about 20°). Then the knee flexes to absorb the impact (to around 40°) and then extends again before toe-off. The quadriceps muscles act to control the shock-absorbing knee flexion movement. Certain strength exercises should be chosen to focus on this range of movement, *eg* limited-range leg press, especially to help prevent the anterior knee pain which women are prone to because of a greater femur Q angle causing more inward rotation of the knee.

Do not overlook the trunk and hips

The other major body part that requires strength training for running is the trunk and hip area. Here the major muscles involved during running are the erector spinae (back), abdominals (stomach), obliques (side) and abductors (top of the bum). These muscles are not so obviously involved with running as the leg muscles, yet nonetheless serve a very important role in pelvis and trunk stabilisation and posture control. Biomechanical research has shown that for the legs to work effectively in propelling the body, the pelvis and trunk area must be rigid and supported by its muscles, otherwise the drive from the legs will be wasted.

These hip and trunk muscles must also be trained for strength endurance, for similar reasons. However, since they do not work as dynamically as the leg muscles, the exercises chosen should reflect their more static, supporting role. These muscles are best trained with a combination of isometric or static exercises and slow, controlled dynamic exercises of small, specific range.

For example, lying on one's front over the end of a bench and extending the arms out into a Superman position and maintaining it is an isometric exercise for the back muscles. Three sets of 10 x 10 seconds holding a straight line from the back to the hands will help maintain an upright posture as the muscles must hold the back and shoulder girdle in a rigid extended position.

An example of a slow and controlled exercise which targets a small range is the reverse curl or reverse crunch exercise for the stomach. This involves lying on one's back with legs fully bent. Then, raise the hips an inch off the floor by pulling with the lower abdominals and lower again, keeping the legs completely still. Here the abdominal muscles have to work continually to raise the pelvis and then lower it again, even though it is a small range of movement. This kind of exercise is more relevant to posture control than the more conventional sit-up. After all, when we run we keep our upper bodies still, so being very strong at flexing the trunk forwards is not necessarily related to efficient running.

In general, the hip and trunk muscles must be trained for strength endurance (low resistance/high volume) using static exercises and exercises with specific ranges of movement for posture control. The choice of exercises must reflect the need to maintain a rigid back with a level pelvis to be able to push off with the legs. Balanced strength in this area also helps prevent lower back and hamstring injuries. In my opinion, the trunk and hip area is very important for 10km strength-training programs; strong legs will only do so much if the trunk is not a well-supported, rigid structure. Would a motor racing team put a Formula 1 engine in a car with a Formula 3 chassis?

Training the upper body

To complete the strength analysis, we must consider the upper body. This area is less important for 10km running, but for an all-body, balanced strength program some upper-body exercises should be included. Upper-body strength will also help with posture and an effective, easy arm action. Once again, I would recommend a strength endurance emphasis.

A practical way to train the upper body without devoting too much time to it would be to cover most of the major upper body muscles in two or three exercises – for example, seated row together with bench press, or pull-ups together with dips, would target most of the chest, shoulder, upper back and arm muscles.

Summary

To summarise the strength training program for the 10km, all the major muscles involved in running need to be trained with a strength-endurance emphasis. The exercises chosen also need to be biomechanically relevant in terms of movement, single-legged and foot-fixed, and any important joint ranges of movement. This will improve the power and efficiency of running action and help reduce knee injury risks.

Training the trunk muscles for endurance, using static and postural-specific exercises will increase efficiency by improving the rigidity and support of the trunk. It will also help reduce low back and hamstring injury risks. Exercises covering the upper-body muscles will complete a balanced strength program that is specifically targeted to the athlete's event.

This kind of analysis can be done for any event or sport. First, the correct muscles and movements have to be pinpointed and the role they play in the sport determined. From this the relevant strength-training exercise protocols can be designed for the muscles involved. Women athletes should definitely use this method as the starting point for their essential strength training requirements.

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Raphael Brandon

The Press-ups test

The objective of this test is to assess the athlete's upper body strength.

Required resources

To undertake this test you will require:

- Flat surface
- Mat
- A partner.

How to conduct the test

The Press-ups test is conducted as follows:

- Lie on the mat, hands shoulder-width apart & fully extend the arms – *see Figure 1*
- Lower the body until the elbows reach 90° – *see Figure 2*
- Return to the starting position with the arms fully extended – *see Figure 1*
- The feet are not to be held
- The push-up action is to be continuous with no rest
- Complete as many press-ups as possible
- Record the total number of full body press-ups.

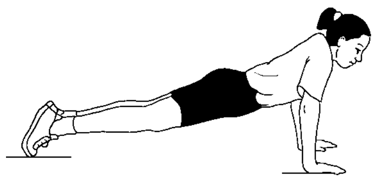

Figure 1

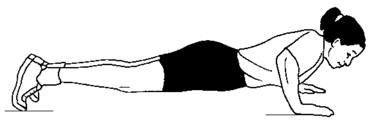

Figure 2

Female athletes tend to have less relative strength in the upper body and therefore can use the modified press-up position to assess their upper body strength. The test is then performed as follows:

- Lie on the mat, hands shoulder-width apart, bent knee position & fully extend the arms – *see Figure 3*
- Lower the upper body until the elbows reach 90° – *see Figure 4*
- Return to the starting position with the arms fully extended – *see Figure 3*
- The feet are not to be held
- The push-up action is to be continuous with no rest
- Complete as many modified press-ups as possible
- Record the total number of modified press-ups.

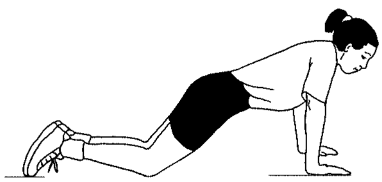

Figure 3

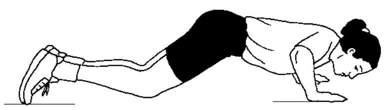

Figure 4

Analysis

Analysis of the result is by comparing it with the results of previous tests. It is expected that, with appropriate training between each test, the analysis would indicate an improvement.

Assessment

The table below provide standards for scoring the full body push-up and the modified push-up test.

Number push-ups completed					
Rating	Age				
	20-29	30-39	40-49	50-59	60+
Full body push-up					
Excellent	>54	>44	>39	>34	>29
Good	45-54	35-44	30-39	25-34	20-29
Average	35-44	25-34	20-29	15-24	10-19
Fair	20-34	15-24	12-19	8-14	5-9
Poor	<20	<15	<12	<8	<5
Modified push-up					
Excellent	>48	>39	>34	>29	>19
Good	34-48	25-39	20-34	15-29	5-19
Average	17-33	12-24	8-19	6-14	3-4
Fair	6-16	4-11	3-7	2-5	1-2
Poor	<6	<4	<3	<2	<1

From Pollock, M.L., et al: *Health and Fitness Through Physical Activity*. New York: John Wiley & Sons, 1984.

Target Group

This test is suitable for active individuals but not for those where the test would be contraindicated.

Reliability

Reliability would depend upon how strict the test is conducted and the individual's level of motivation to perform the test.

How much weight are you pressing?

When you perform the full press-up *(Figure 1)* you are lifting approximately 75% of your body weight and in the modified press-up position *(Figure 3)* you are lifting approximately 60% of your body weight.

Brian Mackenzie

Module 2

Power

Power

Power is the rate at which mechanical work can be performed or the rate at which energy is expended in a physical process. It is a measure of how much energy is created in each second that passes, the size of the force applied and the velocity at which it is applied. Power {(Force x Distance) / Time} represents the product of strength and speed of movement, expressed in watts or joules per second.

Power is a measure of force being applied at speed and therefore is a fitting commodity in the majority of sports requiring fast dynamic movements such as sprinting, jumping, throwing, weightlifting and most field sports.

Overview of the articles in this section

- John Shepherd in his article 'Add power to your punch with plyometric exercise' explains how to plan appropriate plyometric exercises into your annual training program
- Stephen Garland explains how to make your muscles more fatigue-resistant in his article 'How to increase speed and power by recruiting more fast-twitch muscle fibres'
- Raphael Brandon in his article 'Strength or power: which matters most for peak athletic performance?' explains the benefits of quality versus quantity in weight training
- Brian Mackenzie provides an example of a power test that can be used to monitor the explosive power of your legs in his article 'The Jumps Decathlon'.

The articles in this section are applicable to most sports.

Add power to your punch with plyometric exercise

Do you ever look in awe at top sprinters and realise just how fast they are running? Maurice Green (USA) would get a speeding ticket in built-up areas! And what about the slam-dunk in basketball? How on earth do players like Kobe Bryant leave planet earth and attain such height? And what of Matthew Pinsent and James Cracknell? Unbridled, these rowers would seem to be able to tear their boat apart! Wherever you look in the world of top-class sport, power counts; and one of the best ways of developing this most precious commodity is through plyometric training.

Plyometric exercises are based on the understanding that a concentric (shortening) muscular contraction is much stronger if it immediately follows an eccentric (lengthening) contraction of the same muscle. It is a bit like stretching out a coiled spring to its fullest extent and then letting it go: immense levels of energy are released in a split second as the spring recoils. Plyometric exercises develop this recoil or, more technically, the stretch/reflex capacity in a muscle. With regular exposure to this training stimulus, muscle fibre should be able to store more elastic energy and transfer more quickly and powerfully from the eccentric to the concentric phase.

Unlike traditional weight training, plyometric drills can closely mimic both the movement pattern and the speed of execution of actual sports performance. While a sprinter's foot may be in contact with the ground for just 0.084 seconds, and even running at a moderate pace can result in a foot strike time of 0.2 seconds, most standard weight-training lifts, performed at their quickest, take 0.5 to 0.7 seconds to complete. A plyometric drill will match runners' ground contact times, while at the same time generating a significant amount of force.

One piece of Soviet research showed that under certain conditions athletes could display brief (in the range of 0.037 to 0.067 seconds) plyometrically induced muscular tensions equivalent to 1,500 to 3,500kg, although it should be noted that this example was probably based on eccentric (drop and hold depth jumps from a great height) rather than the more familiar types of plyometric drills, of which more later. So you can see why weight training for sport can be limiting when it comes to specific training transference and why plyometrics is a great way to address power needs.

To get the best out of plyometrics you should ensure adequate pre-conditioning. Some authorities recommend that an athlete should be able to half squat at least 1.5 times their body weight before embarking on a plyometric program, but this may be an excessive requirement, particularly if an athlete is planning to embark on a progressive plyometric conditioning program, beginning with low-intensity drills before progressing to the more intense *(see table 1, opposite)*. As with all 'new' training experiences, progress should be incremental.

Despite my seemingly dismissive comments about weight training, it should not be discounted as a means of generating specific sports-related power. Weight training still has a vital role to play in terms of laying the foundations for greater power and pre-conditioning an athlete for plyometrics. A larger and stronger muscle (built up by weight training) will be able to generate greater force plyometrically, and strengthened tendons and muscles will be less prone to strains and pulls. It is also possible to combine weight training with plyometrics for a heightened fast twitch muscle fibre response. When it comes to selecting the right plyometric moves, the coach or athlete needs to consider the specifics of their sport, the athlete's maturity, level of pre-conditioning and ability to pick up what can be a complex skill. Single leg moves are often more complex and more stressful than double leg moves. Compare squat jumps to alternate leg bounding over 20 metres, with either a single or double arm shift or a 15 metre run-on. The complexity and speed component of the latter is significantly greater than the former. It is likely that a beginner, or even a moderately conditioned individual, would not be able to perform even the first bound without collapsing, let alone a series over 20 metres.

Plyometric drills ranked by intensity

Table 1

Type of plyometric move	Examples	Intensity
Standing-based jumps performed on the spot	Tuck-jumps Split-jumps Squat-jumps	Low
Jumps from standing	Standing long jump Standing hop Standing jump for height	Low-medium
Multiple jumps from standing	5 consecutive bounds 2 x 6 bunny jumps Double-footed jumps over 4 hurdles Double-footed jumps up steps	Medium
Multiple jumps with run-up	3 x 2 hops and jump into sand pit with 11 stride approach 2 x 10 bounds with a 7 stride run-up	High
Depth Jumping (Recommended drop height 40 to 100cm – the greater the height the greater the strength component, the lower the height, the greater the speed)	2 x 6 jumps – down and up Run to hop off low box onto one leg landing followed by three subsequent hops Bounding uphill	High Very high Very high
Eccentric drop and hold drills	Hop and hold 5 times Bound/hop/bound/hop and hold over 30m (To perform the above two examples the athlete literally stops on each landing before springing into the next move where required.) Drop and hold from height above 1m	High High Very high

Always err on the side of caution when selecting your moves. Table 1 *(p. 23)* ranks various plyometric lower limb drills in order of intensity. Those new to this type of training should be sure to start with the low-intensity moves when introducing plyometrics into their training program. You should wear well-cushioned trainers and perform the drills on a yielding surface, such as a running track or sprung floor.

Eccentric drop and hold jumps

These drills, although utilised in training and research from the 1960s onwards, have not been as prevalent in training programs as the other drills referred to in the table. Eccentric drills focus on the plant and absorption phase of a dynamic movement and forsake the concentric phase in the stretch/reflex sequence. They are advocated because of their huge force absorption potential and as a further conditioner of the stretch/reflex.

Poor interpretation of the work done by Yuri Verhoshansky (the former Soviet sports scientist, known as the 'father' of plyometric research) sometimes resulted in subjects being asked to perform depth jumps (*ie* rebound on landing) from very considerable heights (*eg* in excess of 3m) with obvious potential for injury. (I myself was once asked to perform this form of eccentric training from a similar height but refused on the grounds of sanity!) The height itself is a major fear factor, let alone the landing!

However, if implemented sensibly and from lower heights, or in the form of 'bound/hop and hold' drills, eccentric power training can be an effective way of further developing power. It is yet another way to overload muscles and thus avoid stagnation, and maintain training progression in seasoned athletes. Both coach and athlete need to be aware that eccentric training is likely to cause muscular soreness even in the well-conditioned; but, as with other forms of eccentric training, such as downhill running, one session may be all that is needed to 'inoculate' the body against further soreness.

As with weight or endurance training, you can periodise your plyometric training. Obviously the specific requirements of your sport and your competitive aims for the forthcoming season need to be considered, but there are some general guidelines for progression. The following recommendations are based on the requirements of a power athlete with a single main competition period, but occasional reference is made to the needs of endurance athletes.

Pre-season/early conditioning phase

Plyometric moves such as split squats, jump squats and straight leg jumps can all be incorporated into a circuit. Normal circuit training protocols should be used – *ie* high reps, short recoveries. At this stage of general conditioning they will develop low-level power and general sports-specific movement pattern conditioning, as well as specific endurance. If you are an endurance athlete you could continue this type of training beyond your pre-condition phase and integrate it into your non-track/rowing/cycling sessions. Runners could also incorporate plyometric drills into fartlek-type workouts.

Main power conditioning phase

Athletes who are sufficiently skilled should use drills from the medium-intensity categories in Table 1 *(p. 23)* during this phase of training. Runners should progress to single leg variants as these will have the greatest relevance to their sport. Do not neglect lower leg drills such as straight leg jumps – where the athlete literally 'bounces' up and down on the spot. These will improve specific calf and Achilles tendon power, leading to optimum foot-strike and force return when running.

Middle and long distance runners could incorporate bounding and hopping into the warm-up stages of their track sessions; they could also carry out hill training to develop running-specific power as well as maintaining plyometric drills within their circuit training.

Pre-competition phase

During this period athletes should concentrate on quality plyometric drills that replicate the speed and movement patterns of their chosen sport. Select drills from the high-intensity examples in the table, but ensure quality and do not allow fatigue to impair performance.

Competition phase

In power sports the activity itself will act as the prime conditioner: nothing beats a competitive situation for optimum power expression. But in training, athletes should perform high-quality plyometric drills in low numbers, well away (7 to 10 days) from important competitions. Endurance athletes could continue with medium/high-quality drills as part of their warm ups or as part of their low-intensity workouts.

Volume and intensity guidelines

The recommended volume of specific jumps in any one session will vary with intensity and progression goals. For jumps on the spot or from standing, measure the volume in terms of foot contacts. As a guide, a beginner in a single pre-season workout could perform 60 to 100 foot contacts of low-intensity exercises.

The intermediate plyometrics exponent might be able to do 100 to 150 foot contacts of low-intensity exercises in one workout and 100 of moderate-intensity exercises in another, while an advanced exerciser might be capable of 150 to 200 foot contacts of low-to-moderate intensity exercises in a single session.

Intensity is the key: the more dynamic the move and the greater the power generated, the fewer foot contacts are required. As training phases progress, maintaining quality is crucial and the number of foot contacts should be reduced, as optimum power and speed need to govern performance. Bounding and hops are best measured in terms of sets and repetitions, distance covered and whether they are performed from a standing start or with a run-on. Verhoshansky recommended incorporating a maximum of 5 to 10 bounds per set into a session, with no more than 50 to 75 ground contacts. If a run-on is used, the number of reps should be reduced.

For optimum sports-specific training effect performers should not allow themselves to become fatigued. Rest between sets should be in the region of 1 to 2 minutes; successive depth jumps or drop jumps should be separated by intervals of at least 15 to 30 seconds – or even longer if very intense multiple hops and jumps routines are being performed. Such recovery intervals will allow the stretch reflex mechanism to return to optimum capability.

In terms of number of sessions, 2 to 3 per week should suffice – but they should not be performed on consecutive days or 7 to 10 days before important competitions. Those new to this form of training may experience an initial decline in their performance until they become accustomed to the training method.

John Shepherd

How to increase speed and power by recruiting more fast-twitch muscle fibres

Slow and fast twitch muscle fibres are adapted, both structurally and biomechanically, to enable them to perform specific functions. It is common sense that athletes should want to enhance these adaptations, thus making their muscles more fatigue-resistant (slow twitch type), or powerful (fast twitch).

It is often said that people are born with speed, whereas endurance can be trained. To some extent this may be true, and the difficulty in training for speed can only help to reinforce the belief. Nevertheless, real improvements in speed are possible, and this article attempts to suggest ways to overcome some of the training difficulties.

One problem with training fast-twitch motor units is that the units are recruited in an orderly fashion. Imagine a muscle slowly developing tension. As tension increases, units are recruited according to Henneman's size principle – those with the smallest-diameter motor neurones are recruited first, and these tend to be slow-twitch (ST) fibres. As force increases, more and more fast-twitch (FT) units are recruited. So fast-twitch fibres for such a contraction are only recruited when the neural stimulus is high – at high forces. For sub-maximal contractions, the muscle fibres that are not recruited will thus most likely be FT.

Fast-twitch fibres are also, of course, recruited during high-velocity contractions. But, similarly, only the absolute maximum velocity of contractions will guarantee a maximal activation of the fastest fibres – the preference will always be to recruit the ST first.

This is what is meant by the high threshold of FT motor units – they require a large stimulation to be activated. The stimulation originates in the brain and is transferred by motor neurones to the muscles. It appears that the best and, perhaps, only strategy for speed training is therefore to train maximally (whether that be force, speed, or a combination of the two), which puts a great burden on the athlete's body and mind.

Complex training

Complex training aims to reduce this high threshold of FT motor units by first performing resistance exercises in order to 'sensitise' the FT fibres, and then carrying out more sports-specific exercises (in terms of technique and speed) such as sprinting or bounding.

In a recent study (1998), Trimble and Harp [4] asked 10 young male and female subjects to perform a vigorous bout (80 activations at maximum intensity) of prone concentric-eccentric (calf press). Before and after the exercise, while the subjects were relaxed, the researchers electrically stimulated the nerves leading to the gastrocnemius and soleus muscles, which led to a contraction. The electrical activity of the muscles (which is known as the Hoffman or H-reflex) in response to this stimulus was measured using electromyography.

The scientists found that, immediately following the exercise bout, for the same electrical stimulation as before, there was less electrical activity of the contracting muscle. That is, the muscle was less sensitive to stimulation – its threshold had increased. This could be due to depletion of the nerve-to-muscle chemical transmitter, because of the repeated contractions. However, a couple of minutes later this H-reflex was enhanced in some cases – the phenomenon known as post-exercise potentiation, which is not often seen for volitional contractions. So here we have an intense exercise bout leading to an increase in the ability of the muscle to contract forcefully – the principle on which complex training is based.

Reducing the inhibition

But what might the mechanism be? In order to control muscle contractions, perhaps in an effort to protect the muscle from damage, the nervous system is designed so that for every stimulatory nervous input causing a muscle to contract, there is a corresponding inhibitory input. It is thus logical to suppose that you can increase the force of a contraction either by increasing the stimulatory input or by decreasing the inhibitory input. It has been shown in other studies that the inhibitory input is reduced when an isometric contraction is sustained. Similarly, Trimble and Harp suggest that their intense exercise bout caused an increase in excitability of the muscle fibres due to the removal of this inhibition. So rather than a muscular change, we thus have a neural change which may lead to the ability to recruit and hence to train the high-threshold muscle fibres. This may become a long-term effect – studies of other systems in the brain such as memory demonstrate that these short-term charge effects become long-term. If you can train your brain neurones to have a low threshold for activation, why not motor units? In fact, the early strength gains seen in previously untrained individuals before muscle-mass increases are usually attributed to nerve rather than muscle-fibre adaptations.

Maximise strength, minimise mass

Weight (and hence strength) training is a necessary part of the speed athlete's development, as muscle needs to move quickly against a resistance. However, another issue for the speed athlete is his power/weight ratio, so athletes should maximise the strength gain while minimising mass gain. Hypertrophy due to an increased content of contractile proteins is an obvious and necessary product of resistance training. But it is often found that subjects cannot voluntarily activate all of their motor units, so rather than developing more muscle, a sensible strategy might be to activate these unused fibres, hence reducing the so-called 'strength-deficit'.

A study by Burle and Werner [(1)] in 1984 tackles these issues as well as those raised by Trimble and Harp [(4)]. They compared three different strength-training methods. The 'Max' group performed repeated maximal strength efforts by lifting for 8 sets of 1 to 3 repetitions at >90% 1RM. The high forces required will lead to maximal stimulation of nearly every muscle fibre, including the high-power fast twitchers. The 'Power' group performed their movements as rapidly as possible, with resistance at only 45% of 1RM, in 5 sets of 7 repetitions. Again, this would lead to intense activation of the fast fibres for every repetition. The third group, 'Rep', carried out a program which is perhaps typical of body-builders – repeated efforts to failure, which usually means 3 sets of about 12 repetitions at 70% of 1RM. This session is based on the notion that metabolic depletion causes hypertrophy, which is indeed exactly what happens. After 12 weeks of training, all three groups showed a similar increase in isometric maximal strength (about 20% increase), but the 'Rep' group showed about twice as much of an increase in muscle cross-sectional area as did the 'Max' and 'Power' groups.

The researchers attributed this increase in strength in the 'Max' and 'Power' groups to an increase in the subjects' ability to voluntarily stimulate fibres that they already possess by increasing the number and frequency of discharging motor neurones. We are seeing an adaptation of the nervous system here. An increase in the ability to exploit previously difficult-to-recruit fibres may have important implications when it comes to producing high-velocity movements, because not only is there increased fibre recruitment but these newly-recruitable fibres are likely to be high-power ones. The stimulation and adaptation of the nervous system is the key to producing and improving speed and power.

Do not neglect skill training

There is another aspect of muscle-fibre recruitment which needs to be borne in mind when designing speed training protocols – speed training must be integrated with skill training. Performance of highly technical and coordinated movements requires fine control of the timing and levels of muscle recruitment. This can be learned, producing a 'motor-control program' in the brain, which is the 'memory' of the movement. However, if the control program for a high jump, for example, tells the slow-twitch fibres to contract, then while the jump may be technically perfect, it will not be the maximum that the athlete has the potential to achieve. So the athlete must train his control program using those muscle fibres which he/she will want to use in a competitive situation – the principle of training specificity. Indeed, it is more difficult to produce technically correct high-speed movements – imagine dribbling a football at walking pace and then at Michael Owen pace. Every time an athlete performs a technical exercise at a level below that expected in competition, he/she is training the wrong fibres. In fact, almost all day-to-day activity counteracts the effects of power training because it is the slow fibres that are being used. If athletes think they can take it easy in training, going slowly to make sure they 'hit the positions', then they run the risk of disaster in competition when they hope to speed the movements up.

To sum up, power athletes need lots of well-trained FT fibres producing high forces at high velocities, which are recruited not only in training but also in competition. To do this, they must train at high intensities to produce the required nervous stimulation and subsequent nervous and muscular adaptation.

You can see that it is not an easy life for a power athlete. Too often the worth of a training session is measured in terms of the amount of time the session lasted, or feelings of 'muscle burn' or breathlessness. But what really counts is the intensity of each individual movement. Endurance athletes take note – when you see a shot-putter apparently taking it easy because he/she is not breathing hard or sweating, just watch how much effort he/she puts into each throw.

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Stephen Garland

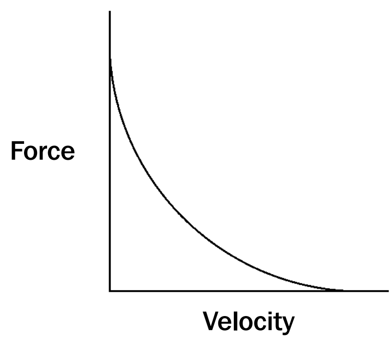
Strength or power: which matters most for peak athletic performance?

Do you strength train for your chosen sport? And do you believe it makes you faster as well as stronger? If so, you could be barking up the wrong tree and might be better advised to work on your power.

Let me explain why. Figure 1 *(below)* represents the theoretical relationship between concentric muscular force and muscle contraction velocity, or speed. Maximum force is generated by a maximal voluntary isometric contraction (MVIC), which has zero velocity. In theoretical terms, strength is defined as the maximum force of a certain movement. In practice, it is defined by the 1 repetition maximum (RM) load of an exercise in the gym.

The 1RM of a movement will produce slightly less force than the MVIC, as the 1RM is dynamic rather than static. To illustrate this by example, an athlete's maximum squat may be 200kg, this being the weight he/she can lift, just once, with a maximum effort. At 201kg, the athlete would not be able to move the bar; however, if he/she applied max effort the MVIC force would be slightly greater than the force produced during the successful 1RM lift. Nevertheless, for the purposes of most coaches and athletes, it is fair to assume that 1RM is highly correlated with maximum isometric force.

Figure 1: The force-velocity curve



In many cases, the aim of a strength program is simply to increase maximum strength. Athletes typically train with weights between 75% and 95% of 1RM, and after a few weeks their 1RM scores go up, which is great because it means they are stronger. Or is it so great? Look at the force-velocity curve again and note that at the high force end of the curve the velocity of movement is at its slowest. Now think about how an athlete lifts very heavy weights – slowly. This is because it takes time – more than 400m/sec – to develop maximal force within the muscle: it cannot be switched on like a light.

Most athletic movements do not involve slow contractions at near maximum force, but are characterised by mid-to-high velocity. For example, the contact time of the foot during sprinting is about 100m/sec – not long enough to produce half of maximum force. This leads you to think about the benefits of strength training in relation to athletic performance a little more critically. What, you might ask, is the point of being stronger at slow speeds when most athletic movements involve high velocities?

Power – how to generate rapid force

A separate quality quite distinct from strength, which can be developed with training, is power. In simple terms, power is the ability to generate force quickly; it is defined mathematically as force x velocity. If you look at the force-velocity curve *(Figure 1)* once again, you will see that high levels of power will occur in the mid-range of either force or velocity. If an athlete develops greater power, this, in turn, enhances his ability to generate both force (strength) and velocity (speed). This combination of speed and strength may be more useful for athletic performance than strength alone.

The above explanations of the force-velocity curve and the difference between strength and power raise two important questions:

1. Would an athlete benefit more from developing maximum strength or power?
2. What are the key differences between max strength training and power training?

For athletes who are inexperienced in strength training, any increase in maximum strength will tend to increase force across the whole velocity range of the force-velocity curve [1]. This means that increases in maximum strength (greater 1RMs in the gym) will also lead to increases in power and the ability to generate more force at fast speeds. Indeed, research shows that maximum strength is strongly correlated with power, especially in less experienced athletes [2]. This endorses traditional heavy weight training (75 to 95% of 1RM) as a way to improve athletic performance.

But research also shows that max strength development becomes limited beyond a certain point. Once an athlete has reached a high level of strength, any further increases will lead to improvement only at the high force/slow velocity end of the curve. This means no increases in power or force at fast speeds, which, as mentioned, is not necessarily desirable for most athletic movements. In a nutshell, as the athlete becomes more advanced and experienced in strength training, the effects of maximum strength training become increasingly specific to slow muscle contractions.

By contrast, power or 'ballistic' training has been shown to increase power and rate of force production and is more highly correlated with athletic performance than strength training. Power training methods can vary in terms of force and velocity characteristics, since the description embraces a number of different approaches. Plyometric jumping or throwing exercises tend to use higher velocity and lower force, whereas Olympic lifting exercises – *eg* power cleans – use higher force and lower velocity. Between these two extremes lie ballistic weight exercises, such as barbell squat jump and bench press throw, which employ moderate forces and velocity.

The benefits of each method differ slightly:

- Plyometric exercises promote high movement speed, fast twitch fibre recruitment and elastic tendon energy release
- Olympic lifts involve very high power outputs, high rates of force production and increases in muscular co-ordination of whole-body movements, such as combined ankle, knee and hip extension
- Ballistic weight exercises are very useful for developing high power in specific areas of the body – *eg* arm extension power with bench press throws – and will result in high rates of force production and muscle activity in the specific muscle groups involved.

There is a good logical argument for training with exercises at specific loads that produce the maximum amount of power for that particular movement. Power has been shown by research to be highly correlated with level of performance, and training which develops the maximum power output will increase force levels at the mid-to-high velocity end of the force-velocity curve.

Exercises of this type that I recommend frequently to athletes include power snatch, power clean, barbell squat jump, bench press throw and heavy bag rotation throw. These are all functional movements that involve moving moderately heavy loads as fast as possible. To generate maximum muscular power, a reasonable amount of load is required, and so these exercises involve greater power output than plyometric jumps, which use no additional load, or medicine ball throws, which are relatively light. Max power training is a distinct discipline and should be performed in addition to plyometric training, not instead of it.

Research has shown that the maximum power produced on a bench press throw or squat jump occurs with loads of around 50 to 60% of 1RM for the bench press or squat exercises. To develop max power levels in the legs and upper body, you can use 1RM test scores to determine the power training loads. For example, an athlete with 1RM scores of 200kg squat and 120kg bench press would produce max power on the squat jump exercise with a 100 to 120kg barbell and on the bench press throw with a 60 to 70kg barbell. Women may produce max power at slightly lower levels.

The importance of quality training

When performing a max power workout, 3 to 5 sets of 3 to 5 repetitions for each exercise would be effective. Power training must be high quality, as the aim is to recruit fast twitch fibres. For this reason, it is important to take at least three minutes rest between sets and to focus on moving the bar as quickly as possible. Max power training performed at less than max power simply does not work; coaches must encourage their athletes to hit each lift with max effort, while athletes must learn to focus on high-quality execution of the exercises. Power training is not like endurance training, where it is enough just to complete the session; it is how well you train for power that makes the difference.

With the Olympic lifts, such as power snatch and power clean, I have found that, for most athletes, maximum power occurs at slightly less than the maximum load. For example, if an athlete has a 1RM power clean of 100kg, then maximum power will be produced around 85kg. This is probably because most athletes do not have the time to develop the perfect technique and timing of elite weightlifters and tend to produce a better speed of movement and co-ordination at less than maximum load. However, as technique improves the difference is likely to diminish.

There are great transferable benefits for athletes using loads for the Olympic lifts that produce maximum power for that lift. The athletes learn to feel the effort required for max power and speed of the lift and take this increased power into the sporting movement. This is my personal experience of the neural and co-ordination effects of max power training. Again 2 to 4 sets of 2 to 5 repetitions with long rests are recommended.

Many athletic movements, particularly throwing and kicking, involve trunk rotation. Rotational movements are not possible with barbell or weight machines, but standing rotation throws of a heavy bag (15 to 30kg depending on the strength of the athlete) are very effective at producing maximum rotation power, as they involve greater muscular force than medicine ball exercises. The same sets, repetitions and rest as above are recommended for effective training.

To summarise

The main difference between traditional heavy weight training and power training lies in the load and speed of the exercises. Loads of 75 to 95% of 1RM will result in increased maximum strength, while loads of 50 to 60% of 1RM, performed ballistically, will result in increased maximum power. Once an athlete has reached high strength levels, maximum power training may be more conducive to peak athletic performance than further increases in max strength.

How strong does an athlete need to be before the benefits of further strength training become limited? This depends on the individual athlete and his or her chosen event. For example, the shot put is significantly heavier than the javelin and may require higher max strength levels for success. As a guideline, elite levels of strength for a male athlete are 1RM squat of 2.5 to 3 x body weight and 1RM bench press of 1.5 to 2 x bodyweight, while those for a female are 2 and 1.25 x body weight respectively.

Once these levels have been reached, any athlete would probably benefit more from maximum power training than strength training. Having said that, there seems to be considerable benefit in combining the two methods within a periodised program. A phase of maximum strength training followed by, or combined with, a phase of maximum power training is an approach supported by the literature.

Some researchers support the continued use of maximum strength training for power development. For example, Ditmar Schmidtbleicher, a German biochemist who has worked with Olympic athletes, advocates using high-intensity weight training for increased rate of force development, and claims that the results are as transferable across the whole range of the force velocity curve, as they are for novice athletes [3].

However, the quality of performance of the exercise is fundamental to the training benefit. When using near maximal loads for rate of force development training, athletes must attempt to move the bar as quickly as possible, even though the actual lift will be quite slow. That is because it is the voluntary effort of attempting to 'hit the bar hard' with each repetition that produces the neuromuscular benefit of increased rate of force development, even at high loads that are normally associated with slow speeds.

This argument is supported by recent research suggesting there is no difference between the sprint performance benefits derived from strength training slowly with heavy loads or fast with moderate loads [4].

Further research suggests that for 'stretch-shorten cycle' movements, where an eccentric contraction precedes a concentric contraction, maximum strength is highly correlated with initial rate of force production in the concentric phase. By contrast, for concentric-only movements maximum strength is not significantly correlated with initial rate of force production [5]. Given that many sporting movements are stretch-shorten cycle in nature it would seem that maximum strength is important.

In writing this article, my aim has not been to diminish the importance of maximum strength training for athletic performance, but to make athletes and coaches think about a more complete approach to strength and power training in order to optimise performance. Remember that the purpose of strength training for athletes is not to increase 1RMs but to run faster, jump higher or tackle harder.

Improved performance is the ultimate goal, and power is highly correlated with performance – possibly more so than strength. It is logical to assume that training with exercises that produce maximum power outputs must produce improvements in rate of force production, muscle activation and functional co-ordination that are transferable to athletic performance.

Having said that, however, maximum strength is a precursor to power and needs to be developed to a sufficient level to maximise power production, particularly in stretch-shorten cycle movements.

Athletes who wish to continue to benefit from training programs must vary their training. By incorporating both max strength and max power training into a training cycle, or periodisation, athletes can present their neuromuscular systems with a variety of different stimuli, so enhancing the adaptations.

Table 1 *(below)* sets out an example workout for an elite jumper, used during the summer competition phase. The split squats were used to maintain max leg strength levels, while the clean and squat jump were used to develop max power. After following this program of developing power and maintaining maximum strength for 10 weeks, the athlete increased power output on the power clean by as much as 10% (from 2600W to 2900W at 90 kg).

Finally, the quality of exercise performance has a crucial impact on the benefits gained.

Table 1: competition-phase workout for an elite jumper

Cleans	4x3	80% of 1RM	3 minutes rest
Squat jumps	4x4	50% of 1RM squat	3 minutes rest
Split squats	4x5	80% of 1RM	2 minutes rest

Athletes must learn to make maximum efforts, recruiting as many muscle fibres as possible. It is also important for athletes to ensure sufficient recovery between workouts and to plan max power training sessions at times when they are fresh and capable of high-quality lifting.

References:

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Raphael Brandon

The Jumps Decathlon

The Jumps Decathlon is easy to carry out and is an excellent way to test an athlete's elastic strength and can used for developing jumping skills as well as specific strength. The Jumps Decathlon comprises of 10 events:

1. Standing long jump
2. Standing triple jump
3. 2 hops, step and jump
4. 2 hops, 2 steps and jump
5. 2 hops, 2 steps and 2 jumps
6. 5 spring jumps (Bunny hops)
7. Standing 4 hops and jump
8. Running 4 hops and jump
9. 25 metre hop for time
10. 5 stride long jump.

Practical uses

The Jumps Decathlon can be used to gauge whether an athlete is becoming more powerful. The benefits are threefold:

1. If the athlete's scores increase, then their power has increased
2. Weakness can be identified if the athlete underscores and these areas can be worked on
3. Motivational help during the long winter months.

How to conduct the test

For each event allow two three successful attempts recording the best distance/time.

1. **Standing long jump** – place feet over the edge of the sandpit. The athlete crouches, leans forward, swings their arms backwards, the jumps horizontally as far as possible, jumping with both feet into the sandpit. Measure from the edge of the sandpit to the nearest point of contact. The start of the jump must be from a static position

2. **Standing triple jump** – take off foot to remain in flat contact with the ground and free swinging of the non contact leg can be used
3. **2 hops, step and jump** – as per standing triple jump
4. **2 hops, 2 steps and jump** – as per standing triple jump
5. **2 hops, 2 steps and 2 jumps** – the second jump is a two-footed take off
6. **5 spring jumps (Bunny hops)** – 5 successive two-footed bounds (bunny hops) with the feet kept together in a continuous movement
7. **Standing 4 hops and a jump** – as per standing triple jump – repeat test for each leg and record the mean distance
8. **Running 4 hops and jump** – length of run unlimited – repeat test for each leg and record the mean distance
9. **25 metre hop** – start from a standing position – repeat test for each leg and record the mean time
10. **5 stride long jump** – normal long jump rules apply.

Analysis

Analysis of the result is by comparing it with the results of previous tests. It is expected that, with appropriate training between each test, the analysis would indicate an improvement.

Jumps Decathlon tables

Points are allocated from the Jumps Decathlon tables depending on the distance or time achieved. Scores should be compared with the athlete's previous scores to determine the level of improvement. Competition can be based on the improvement from the previous test for each event. The Jumps Decathlon tables are not included here but an Excel calculator can be obtained from www.brianmac.demon.co.uk/excel/jumpsdec.xls

Target group

This test is suitable for jumpers (*eg* long jump, high jump) but not for individuals where the test would be contraindicated.

Reliability

Reliability would depend upon how strict the test is conducted and the individual's level of motivation to perform the test.

Brian Mackenzie

Module 3

Agility

Agility

The multi-dimensional movement demands of field and court games dictate a revaluation of the traditional approach to the development of agility. This demands a systematic multi-factored approach that results in significant improvement in game speed. Possibly we have put the cart before the horse by training agility in isolation without considering the underlying co-ordinative abilities and strength. Full development of co-ordinative abilities provides a repertoire of motor skills that can be adapted to deal with sport-specific movement demands.

According to Dr. Drabik in his book 'Children & Sports Training' the co-ordinative abilities are:

- **Balance** – maintenance of the centre of gravity over the base of support. It has a static and a dynamic quality
- **Kinaesthetic differentiation** – ability to feel tension in movement to achieve the desired movement
- **Spatial orientation** – the control of the body in space
- **Reaction to signals** – the ability to respond quickly to auditory, visual and kinaesthetic cues
- **Sense of rhythm** – the ability to match movement to time
- **Synchronisation of movements in time** – unrelated limb movements completed in a synchronised manner
- **Movement adequacy** – ability to choose movements appropriate to the task.

The co-ordinative abilities never work in isolation, they are all closely related. They are the underlying foundation for agility and the prerequisite for technical skills.

Overview of the articles in this section

- Vern Gambetta in his article 'Agility Training to meet the demands of field and court games' explains how to develop the components of agility
- John Shepherd explains how to developing those explosive rotational sport's skills in his article 'Building rotational power: all you need to know about getting in shape to perform zippy turns'
- Andrew Harrison in his article 'If you want to develop extra quickness and agility, this is the way to do it' explains how to improve your explosive reaction skills
- Brian Mackenzie provides an example of an agility test in his article 'Illinois Agility Run Test'.

The articles in this section are applicable to most sports.

Agility training to meet the demands of field and court games

Strength is fundamental

Agility, by the nature of its demands in terms of stopping and starting, requires good basic strength. Without adequate leg strength there is a limit to the quality of the movement which will significantly affect the ability to train. Leg strength must be developed in parallel with agility work. The forces involved in multiple planes also demand that we take a less traditional approach to the development of leg strength that will transfer to the movement skills.

Begin with body awareness and control in conjunction with strength training. It is not an overnight affair, but part of a longer term systematic development program, based on fundamental movements and the subsequent refinement of those movements. Build progressively into sport skills. Carefully understand the movement patterns of the sport and their position within the sport. Each sport has certain movement commonalities with other sports. Look for those commonalities. Each sport will also have movements that are unique to that sport so understand those and prepare for them. Equipment will often dictate movement patterns and positions, *ie* the glove in baseball, the stick in field hockey and ice hockey, the ball in rugby and football. Therefore train and test agility incorporating the game equipment to get a more accurate picture.

Is playing the sport enough to develop agility?

There is one school of thought that feels it is unnecessary to do any significant agility work outside the practice of the actual sport. The thought process is that practising the movements outside the sport are non-specific work that will not transfer and that it is impossible to duplicate the intensity of the actual practice or a game. I do not share that viewpoint. It is necessary to carefully design drills that tap into the repertoire of motor skills developed through the development of the co-ordinative abilities that make up the components of the movements required in the specific sport. The overload should be progressive and based on sound motor learning principles, sound biomechanics, and adapted to each individual athlete.

Developing appropriate exercises

The approach is to design a hierarchy of exercises that lead seamlessly into the sport's skills. That hierarchy is:

- **First derivative** – the actual movement done at game speed
- **Second derivative** – the movements broken into component parts
- **Third derivative** – basic movements (co-ordinative abilities) that underlie the skill.

Understanding the derivatives means understanding the breakdown of the movements in the respective sport.

Analyse the moments

Use game analysis to determine the movements and game speed. Game analysis will also determine the volume of work in the actual sport, which will in turn determine training volumes and intensities. Essentially what we are trying to do is take the guesswork and opinion out of the whole process so as to be as exact and precise as possible in the selection and prescription of exercise in order to produce an adaptive response that will transfer to the game. I personally have spent too much time drilling for drill's sake. Agility drills with a million cones and sticks look good but what is the benefit? The player gets good at the drill, but the drills do not transfer to the game. The goal with agility drills should be efficient, effortless, flowing movement that transfers directly to the sport. Time the drills whenever possible to provide feedback to the player.

The components of agility training are:

- **Body control & awareness** – the ability to control the body parts and maintain a high level of awareness of those parts in relation to the goal of the movement
- **Recognition and reaction** – recognition is the domain of the actual sport skills involved. Recognition of patterns and cues keys reaction. Reaction is the ability to respond quickly to the required stimulus
- **Starting** – the ability to overcome inertia. In multi-direction sports, starts can be stationary or moving or a combination depending on the sport
- **Footwork** – the hip to foot relationship. Conceptually agility is built from the ground up therefore footwork is the unifying thread in all agility work
- **Change of direction** – initiated by getting the centre of gravity outside the base of support and then regaining control to maintain control and

move in the intended direction. Change of direction involving stopping, which is the key to agility, also incorporates the ability to restart when necessary, regardless of the position of the body.

All these components can be significantly improved through systematic application of specific drills.

The application of speed to sports that require multi-dimensional movements demands an understanding of the concept of game speed. Game speed is not linear track speed. It is the ability to apply all elements of speed to the demands of the game. In fact some of the technical aspects of speed that are rewarded in the sprint events in track and field can be counterproductive to game speed. Very little movement in multi-directional sports is straight ahead for any significant distance. Most movement involves angles, curves, starts, stops and direction changes. Agility and game speed are closely related. Agility is defined as the ability to recognise, react, start and move in the required direction, change direction if necessary and stop quickly. This typically occurs in a time frame of two to five seconds.

How to improve agility

Agility can be significantly improved if we understand and apply some basic principles/concepts:

- **Skill** – open skill occurs when the movement goal is unknown. In a closed skill the movement is pre-programmed. The progression in agility training usually proceeds from closed to open skills
- **Reaction versus reflex** – reaction is the response to a stimulus to initiate movement. It is a conscious act that can be improved through training. Reflex, on the other hand, occurs at the sub-cortical level and cannot be trained
- **Speed as a motor task** – a motor task can be learned; therefore speed can be taught if the motor tasks involved are clearly defined
- **Practice**
  – Massed: the skill is practised until learnt without taking a break. These sessions are good for athletes with high level of fitness and experience and are most suited to fixed practice
  – Distributed: practice is interspersed with breaks which can either be rest or another skill. These sessions are good for athletes with lower levels of fitness and experience and are most suited to variable practice.

Strength qualities related to agility

Effective starting demands a high level of concentric strength to overcome inertia. It is extension of ankle/knee/hip pushing back against the ground to propel the body in the intended direction. Effective stopping demands a high level of eccentric strength demands. It is the proportionate bending of the ankle/knee/hip. Basic strength is a pre-requisite for force production and reduction.

Eccentric strength, the primary requirement to stop effectively, is the ability to reduce force. It also requires tremendous joint stability and control. Force must be produced and reduced in extremely short time frames, therefore the premium is on rate of force development. Ability is needed to handle forces in an eccentric mode up to 12 times body weight and be able to change direction and overcome those forces. This all must be done in tenths of a second. It is developed through exercises that develop unilateral and reciprocal leg strength.

The following table shows the relationship of the strength qualities to the components of agility.

Basic strength	FOOTWORK	Balance, body control and awareness
Speed strength & plyometrics		Starting and acceleration, speed angles & vector
Power endurance		Complex footwork
Maximum strength		Change of direction, stopping

These qualities must be developed in parallel, not in isolation and then put back into the whole. There is overlap and interdependency. The traditional approach was to develop strength through repetition of the movement. Theoretically as the athlete got stronger the movement got better, but it did not. The bad habits and patterns that developed due to improper strength resulted in poor movement mechanics. So even though the athlete was doing the drill, the transfer was negative. Incorrect repetitions led to the acquisition of faulty movement patterns that impeded the formation of correct skills. A more rational approach demands mastery of prerequisite fundamental movement skills that are within the strength capabilities of the athlete. As the athletes strength increases through a systematic strength development program, the complexity of the movements can change in parallel. Given the large window of adaptation open to the developing athletes this can occur quite rapidly.

What is agility work?

Agility work is not conditioning, it is speed development work. That statement has many profound implications. Movements must be mastered before any element of fatigue is brought into the picture. Old myths die hard! Grass drills, mat drills, line drills, agilities until you are ill have no foundation in training theory. In fact this approach is counterproductive in terms of sound motor learning. Incorrect movement patterns are learned and grooved. Does fatigue or so called pressure training fit into the picture? There is no question that the plants, cuts, starts and stops must be able to be done in a fatigued state. But that is not where you start – add reaction, add game situations and then add fatigue when the movements are mastered.

Mix reaction speed and agility

Perhaps the biggest shortcoming in most agility work is the lack of a reaction component. Research out of Australia has shown significantly different patterns of activation on simple cutting tasks done with reaction than the same tasks done without reaction. In short reaction changes everything. Reaction can be incorporated early and often if it is placed as part of a logical progression. Reaction should be practiced to the dominant cue demanded by the game.

Reaction can be to one of the following stimuli:

- **Visual** – tracking ability, narrow versus wide focus
- **Auditory** – different cadences and tones
- **Kinesthetic** – pressure, pushes, bumps and surfaces.

Conclusion

Agility is the key to game speed. It not only has a performance enhancement component, but it can make a huge contribution to injury prevention. An athlete who is more agile will be able to safely get into and out of positions that would otherwise be impossible. This can only be developed through a systematic approach that has a foundation in sound motor learning principles.

Further reading

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Vern Gambetta

Building rotational power: all you need to know about getting in shape to perform zippy turns

Such was the ferocity of Pete Sampras' serves that they were in danger of singeing the net; Irish and British Lions rugby centre Brian O'Driscoll swerves around opponents flat out, like a Formula One racing car taking a bend; discus and hammer throwers, and some shot putters, spin with the grace of ballet dancers before releasing their implements with the power of a nuclear strike.

Developing these explosive rotational sport's skills relies not just on innate ability and technique, but also on specialist conditioning drills and methods.

In this article, I will consider such skills as turning, turning to sprint, turning and throwing, and turning to hit/kick a ball or opponent, from both stationary and moving positions. Although all-over body power is needed to perform these activities, the core (abdominal and back muscles) is fundamental for their optimum performance. This area must be strong enough to maximise the transference of power through the limbs into a sports skill, such as a golf drive or a tennis forehand; it must be able to withstand – and reduce the risk of – injury in training and competition; finally (and crucially), it must be able to generate specific sports power itself.

It is often assumed that athletes who are fast when travelling in a straight line will be fast in any direction. However, research suggests that this assumption may be erroneous. Young and associates researched the impact of straight-line speed training on rotational/change of direction speed, and vice versa [1]. Thirty-six males were tested on a 30 metres straight sprint and were given six change of direction tests, the latter involving 2 to 5 tangent runs at various angles. These tests took place before and after a six-week training period, in which one group focused on 20 to 40 metres straight-line sprints and the other on 20 to 40 metres, 100° angle change of direction sprints.

What did the researchers discover about the impact of this training on performance? Not surprisingly, the straight-line sprinting training improved straight-line sprinting performance. However, this increased zip did not translate into speedier turns. In fact, the researchers discovered that the more complex the change of direction/turning task, the less transference there was from straight-line speed training.

Similarly, the turning/change of direction training gave a major boost to turning/change of direction performance, but had no impact on straight-line speed.

These findings have important implications for athletes and coaches in sports like football and tennis, where players have to constantly rotate in order to make up the ground to perform their various sport-specific skills. It seems that the ability to rotate the body at speed is a highly specific skill requiring specialist conditioning, and that being fast in a straight line is just not enough. Some of the exercises at the end of this article can be used to condition such players' 'rotational muscles'.

Rotational sport-specific strength

Developing greater strength through resistance training is a fundamental aspect of all performers' conditioning routines. Coaches and athletes hope that the strength developed thereby will translate into improved sports performance. However, this can be a very challenging conditioning requirement for those in search of rotational power and speed.

Let us begin by considering weight training: most popular sports conditioning weights exercises, like the squat, power clean and snatch, are performed in a linear fashion and do not reflect the way power is generated in a rotational sports movement, like the discus throw. Although these exercises are relevant in terms of establishing a power base, athletes and coaches need to develop a repertoire of more specialist weights exercises, such as the Russian twist and the wood-chop *(see opposite)*, which are better suited to channelling strength and power into rotational sports skills.

However, the direct relevance of even specialist weights moves to sports performance is open to question. Welch and associates looked at the forces generated in a baseball hit and found that the batter's hip segment rotates to a maximum speed of 714° per second, followed by a shoulder segment rotation of up to 937° per second (2). The product of this kinetic link is a maximum linear bat velocity of 31m/sec. The golf swing, to give another example, can be completed in a mere 250 milliseconds.

Developing the 'wind-up-and-rotate' velocity for these sports through weight training alone would be virtually impossible. This poses fundamental conditioning questions, such as: how can weights (and other resistance training methods) be best employed to enhance specific sports performance skill? And how important is speed of performance? Cronin et al went in search of the answers (3) and reached the following conclusions:

- Developing qualities such as strength, power and rate of force would appear of greater importance than training at the actual movement velocity of a task. It may be that (irrespective of load and limb velocity) the repeated intent to overcome a resistance as rapidly as possible is an important stimulus for functional high velocity adaptation
- Workouts should ideally combine sport-specific training with a heavy or varied training load in order to develop the muscular and neuromuscular co-ordination that will improve functional performance
- The ability of the nervous system to activate and coordinate all the muscles involved in performing a movement is essential.

Former world javelin record holder Tom Petranoff advocates under-speed training when recommending medicine ball exercises – a great training tool for rotational power development. The key to any training is "to train smart, to train slow and get the technique correct before you add more weight or resistance," he advises (4).

This echoes the principle – often enshrined in former eastern bloc coaching methodology – of ensuring that a technique is properly mastered before more power is bolted on. This is particularly important in sports involving rotational movements, where controlled, smooth application of power is crucial, as, indeed, is timing. A golfer could not swing his club speedily at the ball without these attributes, nor could a hammer thrower spin as fast as he was able: too much speed would result in loss of balance and control, with consequent under-performance.

Petranoff expands on this issue by emphasising the need for those performing rotational sports movements to develop an awareness of where their centre of gravity is – a requirement that could be compromised by constantly training at or beyond maximum performance velocities.

Throws athletes and their coaches are well aware of this requirement and spend hours performing various rotations, with or without resistance/throwing implements, in the pursuit of better spatial awareness, body positioning and footwork.

Below are some examples of dynamic conditioning drills in keeping with the theme of this article, some of them quite unusual. Although they are performed at various velocities, all develop the muscles used in rotational movements in a highly sport-specific way.

Weights exercises

1. Russian twist

This exercise mimics the shoulder rotation movement employed in numerous hitting and throwing sports. Sit on the floor with your knees bent to about 90° and get a training partner to hold you down by the ankles. Holding a weights disc with both hands, lower your trunk to a 120° angle, then rotate left and right, stopping the weight at 10 to 15cm from the floor. If specialist equipment that supports the body off the ground is available to perform this exercise, you will be able to rotate even further.

2. Reverse trunk twist

Lie on a weights bench face down, having positioned a barbell across the back of your shoulders. Again you'll need a training partner to hold your ankles down. Rotate your torso left and right, while keeping your hips in contact with the bench. Again, some gyms may have specialist equipment designed for this exercise.

3. Cable chop

This exercise uses a high pulley machine and a triangular attachment to develop rotational power in the shoulders and trunk. Stand facing forward with feet slightly more than shoulder-width apart. Hold the attachment with both hands over your right shoulder. Pull the cable across your body to just beyond your left hip. Complete your designated number of repetitions and repeat on the left side. This exercise can also be performed from a kneeling position.

Resistance/plyometric drills

Plyometric drills are a crucial weapon in the rotational sports power-conditioning armoury. They lead to explosive power development, utilising the stretch/reflex mechanism in muscles to develop and release greater energy. A concentric (shortening) muscular contraction is much more powerful when it immediately follows an eccentric (lengthening) contraction of the same muscle, and this is the basis of plyometric training. During a plyometric drill, muscles operate a bit like elastic bands; if you stretch the band before releasing it, a great deal more energy is generated as it contracts, but when there is no pre-stretch the energy output is more 'flop' than 'pop'.

There are a number of plyometric exercises that can be used to boost the power capacity of the trunk (and other parts), some of them requiring specialist items of kit.

Throwing and catching/passing a medicine ball will develop plyometric power in the torso, legs and arms. Paul Chek, one of the world's foremost authorities on sports conditioning, for golf in particular, recommends the following two exercises for developing rotational power [(5)].

1. The twister

Place a small medicine ball between your legs. Holding your arms out straight at shoulder height, take small hops and rotate your knees to each side so that you land at an angle, first to the right and then to the left. The greater the degree of rotation, the greater the amount of work the obliques (the muscles of the outer abdominal area) will have to perform. These muscles play a key role in dynamic rotational sports skill performance.

2. The medicine ball toss

This is a more familiar plyometric trunk move, in which the performer stands side-on to a training partner (or a wall). The move develops the plyometric stretch/reflex in the obliques when the performer catches the ball with two hands and rotates first away from and then towards the partner/wall before throwing the ball back.

3. Tornado ball wall chop

This piece of kit – a polyurethane ball on a length of sailing rope – was specifically developed for generating rotational power. The 'wall chop' can be performed kneeling, sitting or standing, and with varying angles of 'chop'. For the standing version, position yourself about one metre away from a wall, with your back to it. Hold the tornado ball with two hands, then rotate and swing it, either to your left or right, so that it hits the wall. It will, of course, spring back towards you with great force. You need to be braced and ready to control this reaction so that you can swing back into another chop immediately. It is this rapid transference of power that evokes the plyometric response.

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John Shepherd

If you want to develop extra quickness and agility, this is the way to do it

Squash coaches often describe athletes as 'very quick' or 'agile', but what does this really mean?

'Quickness' describes an athlete's ability to react at a given moment and accelerate in a given direction; it involves and combines acceleration, explosiveness and reactiveness (Moreno, 1994 [1]). Fundamental to the rhythmic combination of these sequences is agility. 'Agility' is encapsulated within quickness. It describes the ability to turn or change direction easily and efficiently, linking the movement between an athlete's exposure to the stimulus (squash ball or opponent's body position) and the point of speed generation (the final step in the direction of a shot to be played – Moreno, 1994 [1]).

These are multi-planar (multi-directional) skills, and by definition are essential for the squash player to develop. Obviously those athletes with limited quickness and agility will reach fewer shots, have restricted ability to play aggressively and, because movement to the ball is slower (resulting in poor body/foot positioning on reaching the ball) will have a reduced shot selection when 'pushed'.

What have we established so far? Squash involves explosive reactions to changing situations, and that those players unable to 'make the shot' will be less successful. So how best to take a squash player and improve their quickness and agility? How best to present the proper stimulus and 'teach' these athletes to achieve more of their full genetic potential?

Traditionally, training programs have targeted these two elements separately. Agility through agility training (hardly surprising) and quickness through plyometric training, but as with the definitions given above the goals and principles of both these types of training overlap. This creates a situation in which, theoretically, plyometric drills that include changes of direction may be categorised as agility drills, while agility drills performed with maximum explosiveness may be classified as plyometric (Roper, 1998 [2]). Such a crossover inevitably allows for the development of advanced exercises that fit the definition of both plyometric and agility training.

It was with this idea in mind that the following session was created.

Session design

Plyometric exercises are aimed at reducing the amount of time spent on the ground preparing to move, with the primary emphasis of most exercises focused upon vertical and forward motion. In a squash game, the next movement could be in the same direction or in an infinite number of possible directions. The design of this training session hinges on eliciting a plyometric-based stretch-shortening cycle but then using this stimulus to isolate the multi-planar movement/foot patterns specific to squash. To recreate 'game play', each drill mirrors a movement on court and as such is performed over short distances focusing on the development of both linear and lateral movements. This is further facilitated by completing the session on a sprung squash court, which allows for optimal movement patterns within certain drills (*ie* drills 1 and 3).

Session drills

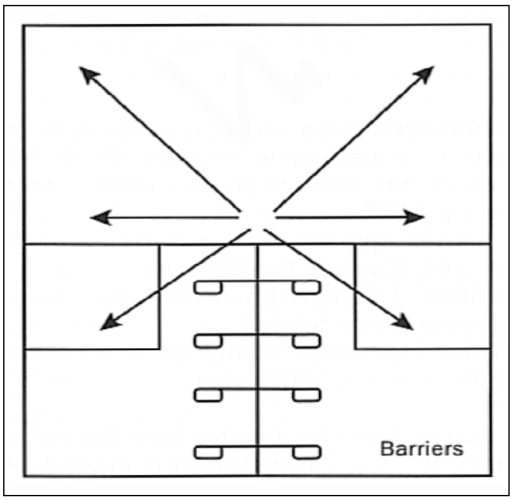

Diagram 1

1. Barrier hop with change of direction and shot *(refer to Diagram 1)*.

Barriers are formed in a row with the last barrier placed so that the athlete will land on the 'T'. The athlete completes barrier hops as normal. While he/she is clearing the last barrier, the coach points to a specific area which corresponds to a specific shot to be played (*ie* front court: lob/drop shot/straight or cross-court drive; mid-court: volley/drive; back court: drive). All shots can be either fore or backhand. The athlete lands two-footed, reacts to the coach's visual cue with a split step, moves to the correct court position and plays the shot. After completing the shot, the athlete pushes back out of the 'shot' in the direction of the T, but for one step only.

This drill develops: starting speed, acceleration, vertical jump capacity and horizontal jump capacity.

2. Lateral barrier hop with 180° turn.

Barriers are formed in a row. The athlete transverses the barriers sideways, landing on both feet, hips facing forwards throughout. While clearing the last barrier, the athlete turns 180°, landing on the outside foot only, pushing off on this leg to change direction back down the row. The athlete lands two-footed back down the row. This is repeated until the required number of repetitions is completed.

This drill develops: ankle stability, acceleration and lateral change of direction.

3. Hexagon drill with change of direction.

Tape is used to create a hexagon on the floor (sides of 20 inches plus), using the T as the centre. The athlete stands in the centre of the hexagon and responds to a starting signal by jumping two-footed across one side of the hexagon and then back to the centre. The athlete proceeds around each side of the hexagon in this manner for a prescribed time period. A visual clue is given to the athlete at the mid-point of the prescribed time, at which point the direction of the hexagon travel is reversed.

This drill develops: ankle stability, acceleration, lateral change of direction and ability to centre body following a change of direction.

4. Split squat jump with cycle.

The athlete begins in a split squat position. The athlete then drives up, the main emphasis coming from the front leg. Mid-jump, the leg positioning is cycled so that the opposite leg comes through to the front and becomes the drive leg for the next repetition. This is repeated until the required number of repetitions is reached.

This drill develops: starting speed, acceleration and linear change of direction.

5. Barrier hops with 180° turn.

Barriers are formed in a row. The athlete hops two-footed over the barriers. While clearing each barrier they rotate 180° in alternate directions. On clearing the last barrier, the athlete reverses the rotation and traverses back down the row in the same manner until the required number of repetitions is reached.

This drill develops: turning speed, ankle stability, vertical jump capacity, horizontal jump capacity and linear change of direction.

NB. All cues are visual – squash-specific. The athlete completes all drills holding a racket – squash-specific. Proper technique throughout is vital. The athlete makes minimal contact with the floor during all drills; there is no land and pause but rather an immediate explosive movement in the direction required.

Using and working within the session

Clearly this is an advanced session designed for the elite squash player. However, its advantage is that the intensity of each drill can be adapted to suit a particular athlete's specific skill level, while still retaining the original emphasis.

The session intensity can be reduced not only by limiting the number of barriers, barrier height or the distance of each hop but also by breaking down each drill to its core movement (for example, removing 180^{o} turn, movement to shot or the use of a racket). Conversely, the session intensity can be increased by including depth jumps or by adding resistance such as a weighted vest. Such variables should be modified for phases of the training calendar, injury potential and the athlete's experience base and level of participation. However, progression should never be sacrificed for a breakdown in technique; this is counter-productive.

I have found that being able to progress an athlete in such a manner is extremely beneficial, allowing for fine tuning of each drill to obtain optimum stimulus. At each stage I find it useful to monitor athletes, allowing for comparison and immediate feedback. I achieve this by timing the athlete to complete a single rep (drill 1), a set of specific numbers of repetitions (drills 2, 4 and 5), or by counting the number of foot contacts/hops possible within a set period of time (drill 3). This, combined with the fact that the athlete can actually see themselves dealing with greater drill intensity and complexity, helps to maintain focus, reduce boredom, and thus maximise results.

Further points

Before any drill work, athletes should complete a general warm-up that includes squash-specific dynamic flexibility movements. This produces several benefits such as improved co-ordination, balance, proprioception and movement speed. However, it must be remembered that for optimal results the athlete should begin the main session fully fresh, so the dynamic flexibility work must be designed so as not to be overly tiring. Post session, static stretching will reduce muscle soreness and increase flexibility (Sobel, Ellenbecker and Roetert, 1995 [3]).

As usual with drills of this type, it is advisable to quantify the volume of the session by the number of foot contacts. The athlete's overall program will dictate the optimal number of sets, repetitions, length of rest periods between sets and the frequency of completion. Nonetheless, the intensity is always maximal.

This session is fundamentally plyometric based and so suitable thought must be given to ensure its safe and effective use, such as training age, flooring, suitable strength level, participation in an overall conditioning program, and correct technique throughout.

And finally

This session is an integral part of the elite squash training programs that I prescribe. Its primary object is to target 'first step' quickness and agility in all directions, but these drills also affect balance, co-ordination, joint stabilisation and foot speed. To date results have been positive. These include both testing data and anecdotal evidence from coaches and athletes.

During the construction of the session, it was my aim to keep the drills as specific to 'game play' as possible. However, it is important to remember that the main emphasis is on developing quickness and agility, not on teaching the fundamentals of squash. As a result, some foot patterns need to be exaggerated to place the correct physiological demands on the athlete.

The combined training approach of this session allows for reduction of training time and ensures that the athlete undertakes agility training with the same explosiveness which is assumed with plyometric drills. Its structure is such that innovative coaches can use the basic premise and develop a specific session not only for squash but for any racket-based event.

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Andrew Harrison

Illinois Agility Run test

The objective of the Illinois Agility Run test is to monitor the development of the athlete's agility.

Required resources

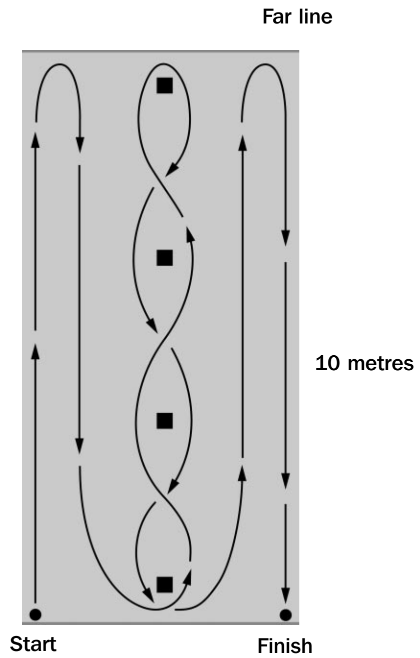
To undertake this test you will require:

- Flat surface – a 400m Track
- 8 cones
- Stop watch
- Assistant.

The Illinois course

The length of the course is 10 metres and the width (distance between the start and finish points) is 5 metres. On an athletics track you could use 5 lanes.

Four cones can be used to mark the start, finish and the two turning points. Each cone in the centre is spaced 3.3 metres apart.



How to conduct the test

The Illinois Agility Run Test is conducted as follows:

- The athlete lies face down on the floor at the start point
- On the assistant's command the athlete jumps to his/her feet and negotiates the course around the cones to the finish
- The assistant records the total time taken from their command to the athlete completing the course.

Analysis

Analysis of the result is by comparing it with the results of previous tests. It is expected that, with appropriate training between each test, the analysis would indicate an improvement.

Normative data for the Illinois Agility Run test

Gender	Excellent	Above Average	Average	Below Average	Poor
Male	<15.2 secs	15.2 – 16.1 secs	16.2 – 18.1 secs	18.2 – 18.3 secs	>18.3 secs
Female	<17.0 secs	17.0 – 17.9 secs	18.0 – 21.7 secs	21.8 – 23.0 secs	>23.0 secs

Table Reference: Davis B. et al; *Physical Education and the Study of Sport*; 2000

Target group

This test is suitable for team sports but not for individuals where the test would be contraindicated.

Reliability

Reliability would depend upon how strict the test is conducted and the individual's level of motivation to perform the test.

Brian Mackenzie

Module 4

Balance

Balance

Balance is the ability to maintain equilibrium when stationary or moving (*ie* not to fall over) through the co-ordinated actions of our sensory functions (vision, hearing and proprioception).

Balance comprises of static balance (the ability to retain the centre of mass above the base of support in a stationary position) and dynamic balance (the ability to maintain balance under changing conditions of body movement).

Overview of the articles in this section

- Walt Reynolds in his article 'How to improve your balance with a balance board' provides an overview of a selection of balance board exercises which will help improve your balance
- Sean Corvin explains the body's dynamic balance capabilities and provides a selection of general and sport-specific balance drills in his article 'Learn to keep your balance with some simple drills'
- Brian Mackenzie in his article 'Standing Stork Test' provides an example of a balance test.

The articles in this section are applicable to most sports.

How to improve your balance with a balance board

Exercises with a balance board are especially effective at improving the strength, mobility, flexibility, and elasticity of the muscles, tendons and ligaments which run between the knees and toes. These structures include the intrinsic muscles of the feet, the plantar fasciae, the plantar and dorsiflexors of the ankle, and the Achilles tendons. All of these anatomical components help to stabilise and control the foot and lower part of the leg during the foot-strike portion of the gait cycle and in particular govern and coordinate 'pronation' – the natural inward movement and rotation that occurs at the ankle immediately after the foot hits the ground. Balance board exercises mimic what happens to the muscles, tendons, and ligaments of the feet, ankles, and lower legs during running – and thus fortify them for the stresses they must endure.

What kind of balance board is best?

Balance boards are made in two general configurations. The first type – the 'rocker board' – has a platform on which you stand and a rectangular strip of wood on the bottom of the platform. The strip on the bottom runs the entire length of the platform (12 to 16 inches) and is typically half to one inch wide and half an inch high. Instability – and thus an increased demand for coordinating force production by the muscles of the feet, ankles and legs – is created by placing this strip on the ground and standing on top of the platform. Obviously, the direction of instability can be varied from front-to-back or side-to-side, depending on how you position your foot relative to the wooden strip, but that is all you can do with a rocker board, and thus instability can really be created in just one plane of motion. Rocker boards are most useful for beginning and intermediate-level balance board trainers. For best results, they should allow for 10 to 15° of motion (*ie* incline/decline of the platform surface).

The second type of board – the 'wobble board' – has a wooden (or plastic) half-sphere on the bottom of the platform and thus provides instability in multiple planes of motion. Since the true motion of the ankle joint during the act of running can never be described as a simple flop forward or backward or a simple roll to the inside or outside (the only motions permitted by rocker boards), it is clear that wobble boards provide much more specific training for runners (*ie* they mimic joint movements much more effectively) and are considerably more beneficial than rocker boards.

The half-sphere beneath a wobble board platform can vary in size from a half-to-two inches high. For two-footed wobble board exercises, the feet are placed on opposite sides of the platform with the half-sphere in the middle. For exercises on one foot, the weight-bearing foot is placed in the centre of the platform, directly over the half-sphere. Wobble boards are most useful for intermediate and advanced balance board trainers and should allow for 15 to 20º of motion (incline/decline of the platform surface) in all planes for best results.

Balance board exercises

The exercises described below are great for improving your strength, co-ordination, and flexibility, but they are by no means the only exertions that can be carried out with a balance board. Ultimately, you can use your own creativity to design and implement additional practical and exciting exercises with the balance board.

Beginning exercises

Carried out on a wooden floor or very firm, carpeted surface using a square rocker board.

1. The two-leg stand and balance with instability from side to side

The rocker strip should run from front to back, parallel to the direction of your feet, with one foot on each side of the strip. Simply hold your position for 30 seconds without letting the edges of the board touch the ground.

2. The two-leg stand and balance with instability from front to back

This time, the rocker strip runs from side to side, perpendicular to the direction of your feet. Complete the exercise by simply holding a balance position for 30 seconds, without touching the edges of the board to the ground.

Both of these exercises develop balance and co-ordination of the entire body – the feet, ankles, legs, hips, trunk, neck and head. They also enhance the so-called 'grip strength' of the feet and toes, which will allow for progression into more difficult balance board exercises.

3. Side-to-side edge taps

Position the rocker board so that the rocker strip is running from front to back, parallel to your feet, which creates side-to-side instability. Then, slowly and deliberately touch or 'tap' the lateral edges of the platform to the ground (left edge, then right edge, left, right, etc.) for about one minute. This range-of-motion and strength exercise should be done under full control, without rapid swings of the board from side to side.

4. Front-to-back edge taps

Position the rocker board so that the rocker strip underneath the platform is running from side to side, perpendicular to your feet, and then slowly and deliberately touch or 'tap' the front and back edges of the platform to the ground (front edge, then back edge, front, back, etc.) for approximately one minute. Once again, perform this exercise with smooth, rhythmic movements, without sudden jerks of the platform.

Both tapping exercises develop gripping strength in the feet and toes and augment the mobility and flexibility of the ankles and feet. Compared to the first two exercises, these tapping routines have a much more pronounced strengthening and mobilising effect on both the plantar fasciae and Achilles tendons due to their dynamic (as opposed to static) nature.

Intermediate exercises

Use a square rocker board placed on a wooden floor or firm carpet, carry out the four exercises described above, but this time on only one foot at a time (first the left foot, then the right). Working on one foot at a time effectively doubles the work load of your muscles, magnifying strength development, and also makes the exercises much more specific to running.

If these intermediate, one-footed exercises are initially too difficult for you to perform without losing your balance, simply place the toe of your opposite (non-weight bearing) foot on the ground 6 to 10 inches behind the balance board. This should allow you to perform the exercise more effectively as you make the transition to one-footed exertions.

Advanced exercises

For these routines, use a round wobble board on a wooden floor or firm, carpeted surface.

1. Side-to-side edge taps

Place one foot directly in the middle of the platform, and note that your board is unstable in all directions (planes). Slowly and deliberately touch or 'tap' the lateral edges of the platform to the ground (left edge, right edge, left, right, etc.) for about one minute. Maintain full control at all times, avoiding hasty motions of the balance board. If the exercise is too difficult at first, place the toes of your other foot on the ground behind the wobble board for better balance. Once the minute is up, repeat the exercise on the opposite foot.

2. Front-to-back edge taps

These are just like the side-to-side exercise, except that you are touching the front edge of the balance board to the floor, then the back edge, etc. Do it for a minute on your left foot and then for a minute on your right.

3. Edge circles

Place your left foot in the centre of the wobble board, and then slowly and deliberately touch the edge of the platform to the floor, rotating this 'edge touch' in a clockwise fashion so that an edge of the platform is in contact with the floor at all times. The actual motion must be very slow and controlled to gain full benefit from the exercise and should be performed for one minute without stopping. As before, place the opposite foot on the ground behind you, if a full one-leg balance proves too challenging. Once you have rotated for one minute on one foot, change to the other.

4. Counter-clockwise edge circles

These are the same as the edge circles, except that you are now rolling the edge along in a counter-clockwise direction.

These advanced balance board exercises develop co-ordination, balance, strength, and mobility in the muscles of the feet, ankles, legs, hips, and trunk. They are part of a progression which began with the simple single-plane exercises (the beginning and intermediate ones) and serve to specifically increase the functional strength and elasticity of the key muscles used during running. The advanced exercises require a high degree of body awareness, and as a result, they must be practiced on a regular basis. Fortunately, they do not take so long to carry out; the advanced exercises, for example, can be completed in five minutes or less. Since the motor skills needed to do them well require repeated exposure for optimal development, it is best to do them at least four to five times a week.

Very advanced balance board exercises

5. The one-leg squat with balance board

This unique exercise strongly develops the quadriceps and gluteals, with a complimentary boost to the hamstrings, as it upgrades strength and improves co-ordination in your feet, ankles, shins, and calves. To complete one-leg squats in the correct way with a balance board, stand with your left foot forward, on the centre of the board, and your right leg and foot extended straight back, with your feet about one shin-length apart. To see if you have the right distance, try squatting down by flexing your left knee and lowering your trunk; as you do so, your right knee should be not far from your left heel. Your feet should be hip-width apart from side to side. Place the toes of the right foot on a block, aerobics platform, or small step which is approximately six inches high. Almost all your weight should be directed through the heel of the left foot, the one which is perched on the balance board. 'Bend' your left leg (*ie* flex your left hip and left knee) and lower your body until your left knee reaches an angle of about 90° between the thigh and lower leg. Return to the starting position, maintaining upright posture with the trunk and holding your hands at your sides. Complete about 8 repetitions, and then shift over to the other leg. After a brief rest, complete

8 more repetitions with each leg. As your co-ordination and strength improve over time, you may increase the number of repetitions and sets.

6. 'Running' on the balance board

Stand upright with your left foot in the centre of the balance board and your right foot off the ground and balance board; your right leg should be flexed at the knee, as though your right leg were swinging forward during the 'swing' phase of the gait cycle. Then, perform a 'posterior pelvic tilt' by tightening your buttocks, contracting your abdominals, and curling your pelvis 'under'. The posterior pelvic tilt is sometimes referred to as 'tucking your tail'; you can think of it as moving the bottom of your pelvic girdle forward and the top slightly backwards. Your head and neck should be in a neutral position and aligned with your upper body. Your arms should be relaxed but flexed at the elbows, as they would be during running. Maintain this basic position throughout the exercise. Simply move your arms forward in an alternating pattern (first right, then left), returning your right arm to your side as your left swings forward, and vice-versa. Both arms should be in constant motion, without pause, and the overall arm and shoulder action should simulate what happens to your arms and shoulders when you run (as you get more coordinated, you may exaggerate the arm swings, taking your arms through a broader range of motion than would be characteristic of running). Repeat the exercise continuously for 30 seconds, and then shift over to your other foot. Over time, you may increase the speed of arm movement, but stay under control at all times. It is also appropriate to progress to three sets of this exercise, instead of just one.

As an extension of this exercise, you may hold dumbbells at your sides with your palms facing in towards your body, and then alternately 'curl' each arm until the dumbbell is in front of your shoulder. The curling action should be rhythmic, and your arms should be moving at all times (raise the right arm at the same time that you are lowering the left arm and vice-versa). Maintain a stable posture throughout the exercise. At first, the dumbbells should be very light, but you can progress to dumbbells which produce significant fatigue after about 15 repetitions. Use a cadence of one arm curl (up and down) about every two seconds, and start with two sets of 15 to 20 repetitions (resting momentarily between sets), before progressing to 3 or 4 sets as your strength and co-ordination improve.

7. Balance board core torture

Lie down, stretching out in a prone position (with face and belly downward), with full body weight supported only by your forearms and toes. The 'catch' is that your forearms should be resting on either side of the centre of the balance board!

In this position, your elbows should be almost directly below your shoulders. Your forearms are resting on the board, pointed straight ahead (parallel to the line made by your body). Your toes (and feet) are about shoulder-width apart, and your toes are the only part of your lower body which are in contact the ground (your toes are not on a balance board, at least not yet!). Your whole body is supported only by your forearms and toes.

'Tuck' your pelvis, as you did with the running-on-the-balance board exertion. This basically means rotating your pelvic girdle by pushing the lower part of your pelvic area toward the ground while the upper part of the pelvis rotates away from the ground. Your hip area does not actually come any closer to the ground (your whole body should be in a fairly straight line from your toes up to your shoulders).

A. Hold this basic position (body supported only on forearms and toes, pelvis tucked) for 15 seconds, and then lift your right leg off the ground and hold it there (roughly parallel with the ground) for 15 seconds (your body will now be supported by your two forearms on the balance board – and the toes of your left foot, which are on the ground). Return to the starting position.
B. Next, lift your left leg in the air and hold it parallel with the ground for 15 seconds, before returning it to the starting position. Your body weight will be supported only by your forearms and the toes of your right foot.
C. Return to the basic starting position, hold this for 15 seconds and then take a one-minute break.

Then, repeats steps A through C. However, once you have completed the second series, stay in the basic position, supported on forearms and toes only, for at least one more minute. Maintain an absolutely straight body posture for the entire period. Then, complete 5 to 10 'Chinese press-ups' (they are like regular press-ups, except instead of supporting your upper body with the palms of your hands, the support is provided by the forearms on the balance board). Try to keep your body fairly linear as you move your torso up and down, bringing your chest down close to the balance board and then back up to the basic position.

Now, flip over so that your back is facing the ground, and lift your body off the ground by supporting full body weight with only the heels of your feet and your forearms on the balance board. Once again, try to keep your body in a fairly linear position, and remember to tuck your pelvis! Follow the same movement pattern outlined above (lifting first your left leg, and then the right), using roughly the same time periods. It is also fun to do more than just lift your appendages. For example, you can bring a knee toward your chest or swing your leg from side to side to increase the 'loading' and stress on your core muscles and shoulders.

The entire sequence outlined above can then be carried out with your toes on the balance board and your forearms on the floor. In this case, the toes of your feet would be positioned on either side of the centre of the board, and you would raise one arm at a time, rather than one leg. Obviously, the balance board-core-torture activity does not mimic the posture or biomechanics of running, but it is devastatingly effective at improving your whole-body strength and co-ordination. You will find it very challenging!!

Final points

Here are six essential points about balance board training:

1) Before starting any of the balance board routines, warm up for ten minutes by performing light jogging, stretching, and range-of-motion activities for the trunk, low back, hips, quadriceps, hamstrings, calves, Achilles tendons, shins and feet. As you carry out the exercises, maintain an upright posture with your trunk at all times, and use smooth, controlled movements – not out-of-control jerks. Devote the first few weeks of your balance board program to developing co-ordination and technique; do not worry about racking up lots of repetitions. As your skill at carrying out the exercises improves over time, increase your movement speed, while maintaining balance and posture.
2) Remember to perform all balance board exercises when you are relatively free from fatigue. For optimal results, balance and co-ordination exercises require that the nervous system be fairly well rested. Somewhat surprisingly, a fine time to do balance board work is immediately prior to a speed workout, since the balance board routines seem to 'wake up' the nervous system and prepare it for intense activity.
3) Since the 'action position' for all athletic activities, including running, incorporates a certain amount of knee flexion, rather than straight legs, be sure to carry out all balance board exercises with your knee(s) slightly flexed.
4) At the very beginning of your balance board training, if you are having trouble with co-ordination, you can stabilise yourself by placing the toes of the opposite (non-weight bearing) foot on the ground behind you during any single-leg exercises. However, do not use your hands for stabilisation, as this largely defeats the purpose of the balance board activities.
5) It is important to remember that you can increase the difficulty of any balance board exercise by holding dumbbells in your hands – and by performing the exercises with your eyes closed. Closing your eyes removes visual cues and particularly enhances your kinaesthetic sense, *ie* your ability to accurately judge the position of your body in space. This increased awareness can help you improve your co-ordination and efficiency of movement.
6) Do not begin your balance board routines until you have recovered from your sprained ankle (or other injury) and your doctor has given you his/her okay. Use the balance board frequently during training to lower the risk of future injury.

Walt Reynolds C.S.C.S

Learn to keep your balance with some simple drills

Many athletes today are using balance training as an integral part of their overall training programs, both for injury prevention and performance enhancement.

Balance is needed by runners when negotiating woodland, by tennis players when reaching for a drop shot and by footballers taking the ball on the volley from slightly behind them. Each of these situations requires the exercise of just the right amount of flexibility and agility at the right time and from the right areas of the body in order for us to execute the desired task, recover and then be able to repeat the same or similar tasks without injury. With balance training, as with most training, the idea is to recreate and manipulate in a controlled environment what we do in an event or game situation.

Maintaining balance means having the centre of mass within your base of support, *ie* with your trunk aligned over your feet. In the past we have tended to believe that perfect balance was best illustrated by standing on one leg and staying as still as possible for as long as possible. However, if we were to take a time lapsed photograph of someone performing that activity over several minutes, even the most skilful mime artist would fail to reproduce it. That is because even when we are trying to remain completely still, our body is constantly oscillating, transferring energy, loading and unloading in a type of perfect chaos. The point is that the body's systems are set up to respond to feedback, and if we were to remain completely still no feedback could be offered.

As well as the centre of mass, we have to appreciate the importance of the centre of pressure within the balance equation. Scientists from the University of Waterloo in Canada have tried to help us understand these concepts by means of a nice analogy with sheep-farming [1]. They describe the centre of mass as a sheep that we need to keep contained within a certain area, while the centre of pressure is the sheep dog. If the latter sees the former straying too far from where it should be, it has to round it up and push it back.

This analogy tells us that balance is a dynamic process which applies to everything we do, including walking or running, where we are perpetually losing and regaining our balance, tennis, where we are loading the system on the forehand, decelerating those forces and exploding out, and football, where we could be rotating to go one way then suddenly have to change direction. The questions we have to ask ourselves as athletes are: how far out of the centre can I go? How far and how fast can I load the system, decelerate those forces and reel myself back in? And am I able to deal with those forces and torques in all three planes of movement?

To understand the body's dynamic balance capabilities you need first to have some grasp of the 'proprioceptive system', which feeds back information about position, movement and balance from the body's other systems, including the central and peripheral nervous systems [2]. A recently-published study from America illustrates the synergy of the proprioceptive system, with key implications for balance training [3]. Eighteen college students were asked to stand on one leg (the balancing leg held in a crossover position to act as a counter balance) with eyes open for 12 seconds on three different surfaces – firm, foam and sloping. They then repeated the test with eyes closed on a firm surface. The researchers found that the ankle was the dominant source of corrective action under all conditions. However, under conditions of greater challenge (as with the foam surface or with eyes shut), there was more corrective action at the hip and/or knee.

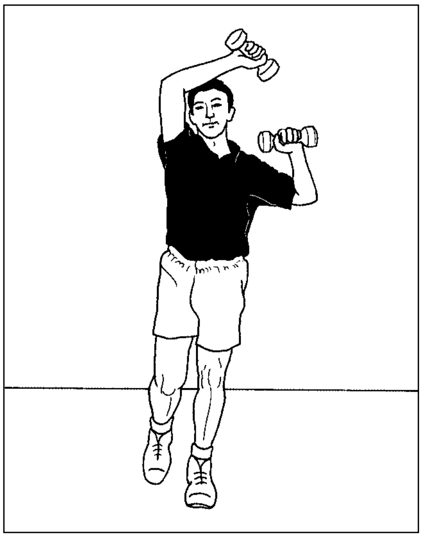
This study shows that when training for balance we can use different 'tweaks' (such as repeating the same drill with eyes shut or while shaking the head) to intensify the effects of the training. Alternating the surface of your balance workout is another good 'tweak': work out on some lumpy, bumpy grass every so often or, for gym workouts, simply repeat each balance drill on an exercise mat to get a different 'feel'.

At this point it is worth advising you not to go to the logical extreme by investing in a wobble board or similar device because there are very few sports that require this level of instability and, as the above-mentioned study points out, the more unstable the surface the more compensatory action is needed further up the chain in the knee, hip, and trunk. Even for ankle rehabilitation, the effectiveness of wobble boards is limited when compared with what you can do simply by using your own body to create instability. These pieces of kit are artificial, do not reproduce any tasks associated with function and suggest a lack of creativity in functional training and rehabilitation.

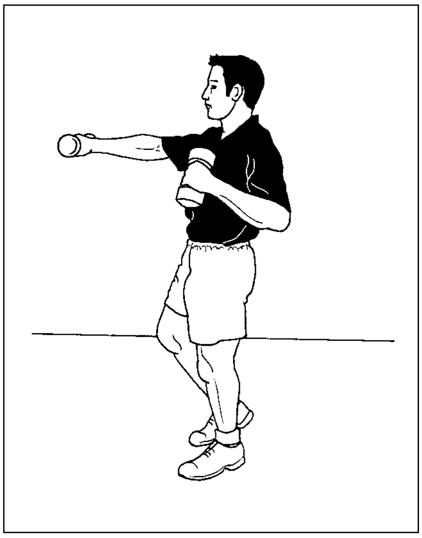
Balance training for your sport should involve replicating components of function associated with that sport, and thus the exercises outlined in this article range from the general to the sport-specific (tennis and football), with various suggested tweaks for purposes of progression. For all runners, the general drills will be best suited to your needs.

1. One-leg punches

Stand on one leg, with the other leg next to, but not touching, the supporting leg. Using 1kg hand weights, alternate punches in the air above the head (10 x each arm), keeping the supporting knee soft, perhaps with a little bounce on each repetition. Then repeat punching out to the side above shoulder height. Now (still balancing on the same leg) alternate crossover punches above the head, still 10 x each arm *(exercise 1)*. Then repeat the whole routine while standing on the other leg. You then repeat the entire drill once more, this time starting with alternate punches in front of you at shoulder height *(exercise 2)*, moving onto lateral punches (out to the side) at shoulder height, and finally crossover punches below head height.



Exercise 1: Crossover punches



Exercise 2: Alternate punches

Suggested variations on this drill are as follows:

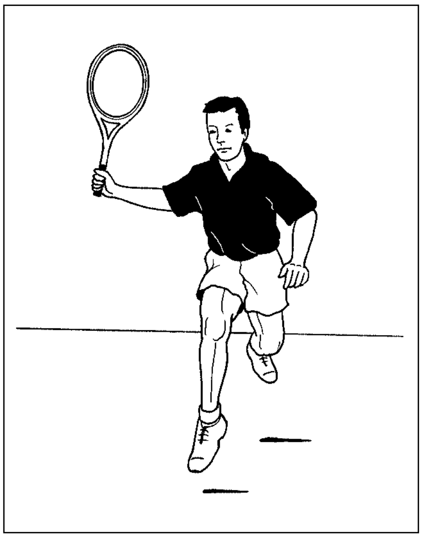
- **Introduce progression** by using slightly heavier weights, or repeating the drill with eyes closed, or on grass or an exercise mat
- **The football tweak**. Stand on the left leg while taking 10 headers from a server 1.5 metres in front of you, heading them directly back. Then, still standing on the left leg, rotate your head to the left while the server feeds you 10 headers from the left and you head them down to the server's feet. The server then feeds you 10 headers from his original position in front of you, and this time you direct the balls to a target at 10 o'clock on the left leg or 2 o'clock on the right leg. Repeat the drills on the other foot, always aiming to keep the free leg off the ground, next to but not touching the supporting leg
- **The tennis tweak.** Standing at the net on the right leg, direct five forehand volleys (above shoulder height) straight down the line and another five cross court. Repeat on the left leg, this time using backhand (if left-handed do the opposite). Then do five overhead smashes on each leg. Then repeat the entire drill with volleys delivered at or below shoulder height.

2. Jump steps

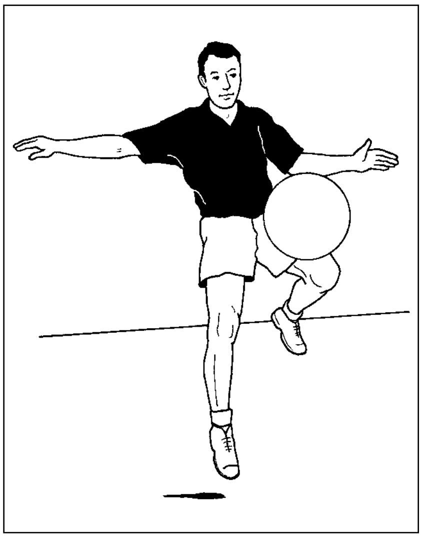
The second series of drills involves a jump step forwards from a standing start onto one foot, holding for a count of two, then returning to the starting position. (The distance you jump will depend on your balance threshold.) Repeat on the other side. This forwards-backwards movement is what is called working in the sagittal plane. Next we need to work in the frontal plane (side to side). So, from the starting position, take a jump step out to the left on the left foot, hold for a count of two, then jump step back to the starting position. Repeat on the other side. The third plane of movement (perhaps the most important) is the transverse plane, involving a posterior lateral jump step. Imagine you are standing in the centre of a big clock face, facing 12 o'clock. First take a jump step back to the 8 o'clock position on the left side, making sure your left foot is pointing to 8 o'clock; hold for two seconds then jump step back to the start. Now repeat to 4 o'clock on the right side.

Variations are as follows:

1. **For progression**, repeat the drill with one or more of the following embellishments to accompany the jump steps:
   - arms above the head
   - hands reaching out to touch landing foot
   - in the transverse plane – rotate arms away from the body when jumping out, then into your body when jumping back
   - arms driving in different directions as you jump step – one forwards, the other out to the side
2. **The tennis tweak.** Take a jump step forwards onto the right foot while taking a forehand volley *(exercise 3)*, then jump step back. Repeat on the left foot with a backhand volley. Now repeat the routine in the frontal plane, jump stepping to the right on the right foot to make the forehand volley and to the left for a backhand. Then repeat using the clock face analogy, jump stepping back to 4 o'clock to make the forehand volley from slightly behind you then repeating on the left to 8 o'clock for the backhand. If left-handed, do the opposite
3. **The football tweak.** Apply the same principles as the tennis tweak, jump stepping with one foot while a server feeds you volleys to strike with the other foot *(exercise 4)*.



Exercise 3: Jump step tennis tweak



Exercise 4: Jump step football tweak

These drills can be easily integrated into your current conditioning program and can be performed when fresh or fatigued. It is a good strategy to vary the time of day you perform these drills as well as the surface you use.

Keep your balance training task-oriented, and try not to concentrate too hard on balancing per se as this just muddies the waters. We do not have to 'switch the core on' to provide balance and stability; the design of the body is such that if it is not switched on there is a bio-mechanical explanation. And if your balance on one leg is worse than on the other, it could mean something as simple as a tight calf or a stiff heel.

Balance is something we need for life. As we get older we need to train a lot smarter in all departments, and balance is no exception.

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Sean Corvin

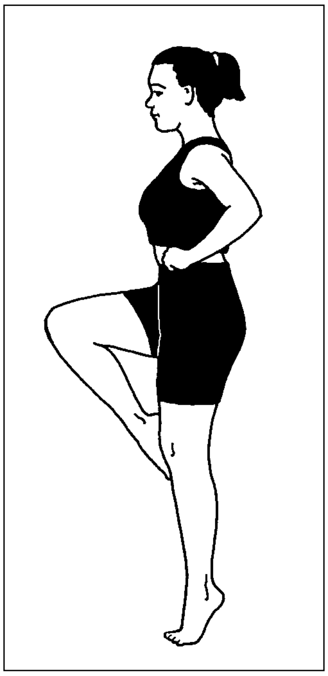
Standing Stork test

The objective of this test is to monitor the athlete's ability to maintain a state of equilibrium (balance) in a static position.

Required resources

To undertake this test you will require:

- Warm dry location – gym
- Stop watch
- Assistant.



How to conduct the test

- Stand comfortable on both feet
- Hands on your hip
- Lift one leg and place the toes of that foot against the knee of the other leg
- Raise the heel and stand on your toes
- Start the stop watch
- Balance for as long as possible without letting either the heel touch the ground or the other foot move away from the knee
- Record the time you were able to maintain the balance
- Repeat the test for the other leg.

Analysis

Analysis of the result is by comparing it with the results of previous tests. It is expected that, with appropriate training between each test, the analysis would indicate an improvement.

Normative data for the Stork test

Gender	Excellent	Above Average	Average	Below Average	Poor
Male	>50 secs	50 – 41 secs	40 – 31 secs	30 – 20 secs	<20 secs
Female	>30 secs	30 – 23 secs	22 – 16 secs	15 – 10 secs	<10 secs

Table Reference: Arnot R and Gaines C, Sports Talent, 1984

Target group

This test is suitable for active individuals but not for those where the test would be contraindicated.

Reliability

Reliability would depend upon how strict the test is conducted and the individual's level of motivation to perform the test.

Brian Mackenzie

Module 5

Flexibility

Flexibility

Mobility plays an important part in the preparation of athletes by developing a range of movement to allow technical development and assisting in the prevention of injury.

The various techniques of stretching may be grouped as static, ballistic and assisted. In both static and ballistic exercises the athlete is in control of the movements. In assisted, the movement is controlled by an external force which is usually a partner.

Static stretching involves gradually easing into the stretch position and holding the position. The amount of time a static stretch is held may be anything from 6 seconds to 2 minutes. Often in static stretching you are advised to move further into the stretch position as the stretch sensation subsides.

Ballistic stretching involves some form of rapid movement into the required stretch position. Where the event requires a ballistic movement then it is appropriate and perhaps necessary to conduct ballistic stretching exercises. Start off with the movement at half speed for a couple of repetitions and then gradually work up to full speed.

Assisted stretching involves the assistance of a partner who must fully understand what their role is, otherwise the risk of injury is high. A partner can be employed to assist with partner stretches and proprioceptive neuromuscular facilitation (PNF) techniques.

Overview of the articles in this section

- Raphael Brandon in his article 'The performance benefits of flexibility training' explains the role of static and dynamic stretching and the link of flexibility to performance and injury
- Phil Campbell reviews a selection of studies on the benefits of stretching and the conclusions that can be drawn from them in his article 'The truth about stretching'
- Brian Mackenzie provides a selection of static and dynamic exercises in his articles 'Dynamic stretching exercises and Static stretching exercises'
- Brian Mackenzie provides a selection of flexibility tests in his article 'Static flexibility tests'.

The articles in this section are applicable to most sports.

The performance benefits of flexibility training

Flexibility training, or stretching, is used in varying forms by practically every coach, athlete and physiotherapist on a regular basis. That is to say, a form of stretching is likely to take place at some point in every training or therapy session. In terms of its scientific basis, flexibility training is probably the least understood of all the fitness components. This article will discuss research findings and recommendations to explain why and how stretching should best be carried out.

What does it mean?

Flexibility is defined as the static maximum range of motion (ROM) available about a joint. The largest limiting factor of static ROM is the structure of the joint itself. Thus, even after endless stretching exercise, there will be a limit as to how much movement is available. In addition, joint structures can vary between individuals, and this must be recognised when assessing flexibility standards in athletes. Most of the variability in static ROM is due to the elastic properties of the muscle and tendons attached across the joints. 'Stiff' muscles and tendons reduce the ROM while 'compliant' muscles and tendons increase ROM. It is these elastic properties that are altered after stretching exercises. When a muscle is held for some time under tension in a static stretch, the passive tension in the muscle declines, *ie* the muscle 'gives' a little. This is called a 'viscoelastic stretch relaxation response'. Passive tension is defined as the amount of external force required to lengthen the relaxed muscle. Obviously, the less external force required, the more pliable the muscle. This increased pliability is maintained for up to 90 minutes after the stretch (Moller et al, 1985).

In the long term, regular static stretching will bring about permanent increase in static ROM, which is associated with a decrease in passive tension.

Experimentally, this was shown by Toft et al (1989), who found a 36% decrease in passive tension of the plantar flexors after three weeks of regular calf stretches. The relationship between static ROM and passive tension has been further supported by McHugh et al (1998). These researchers demonstrated that maximum static hip flexion ROM was inversely correlated with the passive tension of the hamstrings during the mid-range of hip flexion. This suggests that the ease with which the muscle can be stretched through the mid-ROM is increased if the maximum static ROM is improved. The concept that an increased static ROM results in more pliant mechanical elastic properties of the muscle suggests that static stretching is beneficial to sports performance.

Flexibility and performance

Research into the effects of flexibility of stretch shortening cycle (SSC) movements (plyometrics) has shown that increased flexibility is related to augmented force production during SSC movements. In contrast, running studies have shown that flexibility has little performance effect, which is odd because running is a kind of SSC movement. For example, De Vries (1963) showed that while pre-stretching increased static ROM in sprinters, it had no effect on speed or energy cost during the 100-yard dash. Interestingly, it has been shown that stiffer leg muscles in endurance athletes may make them more economical in terms of oxygen consumption at sub-max speeds.

The reason for these converse findings is probably related to the principle of specificity, which seems to underlie all sports training. The sprints and running studies above compared static ROM and stretches with performance, while the SSC research compared active stiffness with performance. Holding a maximum static stretch, and reducing passive tension, is a completely different mechanical action to those practised in actual sports, where joints are moving at fast speeds and muscles are contracting while they are changing length. Thus static ROM may not be an effective flexibility measurement to relate to performance. On the other hand, active stiffness is a measurement of the force required to stretch a previously contracted muscle, and is therefore more sports-specific. It seems logical that the ease with which a contracted muscle can change length will have an impact on the performance of an SSC movement, so active stiffness is a more appropriate parameter to measure flexibility for sports performance.

Along the same lines, Iashviii (1983) found that active ROM and not passive ROM was more highly correlated with sports performance. In this instance, active ROM is defined as the ROM that athletes can produce by themselves, which will usually be less than the passive ROM, which is the maximum static ROM available when assisted manually or by gravity. For example, active ROM would be the height an athlete could lift his or her own leg up in front using the hip flexor muscles, whereas the passive ROM would be the maximum height the leg could be lifted by a partner. Athletes must be able to generate the movement themselves, and this suggests that for improving sports performance it is active

ROM that should be developed and not passive ROM. A sprinter must have enough active ROM in the hip flexors and hamstrings to comfortably achieve full knee lift and full hip extension at the toe-off point of the running gait to ensure a good technique and full stride length. Arguably, any further passive static ROM developed through passive static stretching will not provide any extra benefit, especially since the joint angular speeds during sprinting are very high.

How to improve active ROM

The research suggests that, to improve sports performance, active stiffness should be reduced and active ROM should be improved. This will be more specific than static stretches which reduce passive tension, since sports involve both movement and muscular contractions. Unfortunately, I have found no studies looking at training methods to reduce active stiffness, but one can assume that they will be similar to the methods used to improve active ROM. Alter (1996) suggests that the active ROM can be improved by any kind of active movement through the available active range of motion. For instance, weight-training exercises have been shown to improve active ROM (Tunianyan & Dzhanya, 1984). Ballistic stretches will also develop the active ROM and are endorsed by sports coaches because they have the advantage of being executed at sports-specific speeds. But ballistic stretches must be performed with extreme caution, or they can cause muscle or tendon-strain injuries. If you use them, make sure you begin slowly and with a small ROM, building up speed and full ROM only towards the end.

It seems that, as with endurance, strength and speed training, flexibility training follows the specificity principle. This means that if you want to improve your ability to actively move through a full ROM, then active and ballistic mobility exercises, and not static stretching, is the answer. This supports the use of exercises employed by swimmers and runners during their warm-up routines, such as shoulder circles, bum kicks and high-knee skips. These exercises actively take the joints through their available ROM and thus help to prepare them and the muscles to be more pliable during the subsequent activity. Modern coaching techniques advocate the use of dynamic active mobility exercises as essential components of a warm-up routine in the belief that this kind of exercise will be more beneficial to sports performance and less likely to cause injury than static passive stretches. Unfortunately there is little research to support this. Nevertheless, based on the fact that these exercises will be more specific than static stretches and that, through experience, I have found them to be very beneficial, I would strongly recommend them.

Let's take a specific example. To warm up the lower leg before any kind of running activity, I would first walk 20 yards on the toes with straight legs to warm up the calves and then walk on the heels 20 yards to warm up the dorsi flexors. I would then do 20 ankle flexion exercises with each leg. This involves holding one leg up so the ankle is free to move, first fully flexing the ankle bringing the toes right up and then fully extending the ankle pointing the toes away. Start slowly and then speed the movement up, so you flex and extend quickly throughout the full range of motion. This would be an open-chain exercise.

The next exercise would be to walk with an exaggerated ankle flexion extension, pulling the toes up on heel contact and pushing right up on to the toes at toe-off. Then finally, do the same while skipping, ensuring the full ankle movement is performed at sports-specific speed. The same rationale can be applied to the knee, hip and shoulder, warming up each joint by taking it through the full range of motion, first slowly and then fast, using both open and closed kinetic chain exercises which are specific to your sport. If you perform these kinds of exercises regularly, you should find that, as well as providing an effective warm-up, they will improve your active ROM and specific mobility patterns during sport.

Injury and flexibility

The well-established general rule is that insufficient ROM, or stiffness, will increase muscle-strain risks. More specifically, athletes in different sports have varying flexibility profiles and thus varying flexibility needs in order to avoid injuries. Gleim & McHugh et al (1997) review various studies relating flexibility measures or stretching habits to injury incidence. Studies of soccer players show that flexibility may be important for preventing injuries. For example, one study showed that those who stretched regularly suffered fewer injuries, while another showed that tighter players suffered more groin-strain injuries and a third showed a relationship between tightness and knee pain.

These findings seem to confirm the correlation between muscular tightness and increased muscle strain risks. Yet studies of endurance runners have not shown the same results. For instance, in one famous study by Jacobs & Berson (1986), it was found that those who stretched beforehand were injured more often than non-stretchers. Other running studies have found no relationship whatsoever between flexibility and stretching habits and injury. On the other hand, one study of sprinters found that 4^{o} less hip flexion led to a greater incidence of hamstring strain. The reason for these apparently contradictory findings is the specific nature of each sport. With endurance running, the ankle, knee and hip joints stay within the mid-range of motion throughout the whole gait cycle and therefore maximum static ROM will have little effect. Sprinting and football involve movements of much larger ROM and so depend more heavily on good flexibility.

There are other established biomechanical relationships between flexibility and injury. For example, ankle ROM is inversely related to rear foot pronation and internal tibia rotation. In other words, tight calf muscles are associated with greater amounts of rear foot pronation and lower leg internal rotation. In excess, these two factors can lead to foot, lower leg and knee problems. Poor flexibility in the hip flexor muscles may lead to an anterior pelvic tilt, where the pelvis is tilted down to the front. This increases the lumbar lordosis, which is the sway in the lower back. This in turn can lead to a tightening of the lower-back muscles and predispose the back to injury.

Similarly, tight pectoral muscles can lead to a round-shouldered upper-back posture called kyphosis. During throwing and shoulder movements, this forward alignment of the shoulder can increase the risks of shoulder impingement problems. A flexibility/injury relationship also exists for young adolescents. During the pubertal growth spurt, the tendons and muscles tighten dramatically as they lag behind the rapid bone growth. For young athletes this poor flexibility may lead to injury problems, especially tendonitis type injuries such as Osgood Schlatters. Thus regular stretching is essential for young athletes. Remember it is biological age that counts, so children in the same team or squad may need to pay extra attention to flexibility at different times.

Do not over do it!

As a general guide, when it comes to preventing injury, one should make sure that athletes have a normal ROM in all the major muscle groups and correct postural alignment in the back. For instance, hamstring mobility should allow for 90^{o} of straight leg hip flexion. Any further ROM should be developed only if analysis of the sport's movements suggests that extra mobility is required. The obvious example is gymnastics, where contestants must perform movements with extreme ROMS. A footballer who developed the kinds of flexibility a gymnast needs would be at greater risk of injury since hyper mobile joints become unstable. This relationship has been shown in American football players, with those who have over-developed hamstring flexibility suffering more from ACL strain. A likely reason is that the flexible hamstrings allow the knee to hyperextend more readily.

So the general rule regarding the relationship between flexibility and injury is that a normal ROM in each muscle group will protect against injury. However, specific movements in each sport that requires extra ROM will need extra flexibility development to guard against injury. This may mean that an endurance runner's hamstring ROM may be less than a sprinter's, while a sprinter may not need such a large ROM in the groin as a tennis player, whose sport demands large lateral lunging movements. Extreme ROMs should only be developed out of necessity, since they lead to higher joint-injury risks, just as small ROMs lead to higher muscle strain risks.

What type of stretches?

The job of the coach and therapist is to know the normal ROM for each muscle group and to ensure the athlete achieves and maintains these standards. Christopher Norris's book *(see references)* describes in detail how to assess posture and flexibility in all major muscles and should be used as a guide. If any extra flexibility in specific muscles for specific movements is required, then this should also be developed. To develop flexibility, research suggests (Alter, 1996) that static stretches should be held for at least 20 seconds, possibly up to 60 seconds, to gain a benefit. The stretches should also be performed regularly, ideally twice a day, every day. Stretches should not be painful, and should not cause the muscle to shake. Instead, one should feel a mild-intensity stretch and maintain that position. If the tension eases, taking the stretch a little further and holding the new position will help gains in ROM.

Using partner-assisted stretches and PNF stretching will also produce the same effect. PNF stretches involve applying an isometric contraction against the stretch to invoke a greater relaxation response and thus enable further ROM to be reached. The protocol is for the partner to take the stretch to the initial end point and hold that position. After about 20 seconds, the athlete opposes the position with a strong 10-second isometric contraction pushing against the partner. The athlete then relaxes, breathes out, and the stretching muscle should relax, allowing the partner to take it further. This is repeated. Some research has shown that PNF stretches are very effective, although a study by Golhofer et al (*European Journal of Applied Physiology*, 1998, 77. 89-97) casts doubt on this. These researchers found that while there was a relaxation response post-isometric contraction, it only lasted for a very short time, and so no real benefit was gained.

Getting the mechanics right

Regardless of whether you choose conventional or PNF stretches, by far the most important factor for stretching effectiveness is to choose an exercise with the correct mechanics. The purpose of static stretches is to improve or maintain the ROM of a particular muscle, and the mechanics of the exercise must ensure that the target muscle is being stretched effectively.

For example, a popular, if old fashioned, way to stretch the hamstrings is to perform a touch-toes stretch. However, the touch-toes position requires lower-back flexion, which leads to a change in pelvic position, and so the effectiveness of the stretch for the hamstrings is compromised. The mechanically correct way to isolate the hamstrings is to place one foot slightly in front of the other, leaning forward from the hips and keeping the back arched. Supporting your weight with your hands on the rear leg, you should then feel the stretch in the front leg. This position ensures the back does not flex and the pelvis remains tilted forward, so the hamstrings are lengthened optimally. Try the two different positions for yourself and you should feel a significant improvement in hamstring stretch. You may even find that by keeping your back in a strict arch you may not need to lean forward very far to achieve an effective hamstring stretch.

The message here is that you must ensure that any static stretching exercise you perform allows the target muscle to be lengthened effectively, without being limited by other structures. The mechanics of the stretch should also ensure that the athlete is stable and that there are no undue stresses on any of the joints. For example, the hurdles stretch places a strain on the ligaments of the knee and is no longer recommended. Similarly, with the hamstring stretch discussed above, it is important to support one's weight with the hands on the rear leg so that the lower back is protected. Leaning forward unsupported from a standing position places a great strain on it.

The bottom-line

There is still much to be researched about stretching methods before all the definitive answers can be given. However, it is probably fair to say that some of us need to look again at certain stretching techniques and ask why we do them. In particular, static stretching as part of a warm-up is very common, and yet the research, and logic, suggests that static stretches will do little to help prevent injuries or improve muscle function before an activity. Instead, active mobility exercises, those that take the muscles dynamically through the full ROM, starting slowly and building up to sports-specific speeds, are more appropriate, both pre-exercise and generally to develop active ROM for sports performance.

The role of static stretches is separate from the active flexibility exercises. Rather than as part of a warm-up, static stretches are necessary to develop the correct maximum static ROM that is needed to avoid muscle-strain injuries. Thus static stretches should be used either after training, when the muscles are warm, or in a separate context. These stretches must be effective, safe and stable in terms of their mechanics. As mentioned, a normal ROM in all muscle groups, plus any sports-specific ROMS, should be developed or maintained with static stretches following the above guidelines. If flexibility is well below normal, then PNF stretches may be considered to improve flexibility more quickly.

Some of you may not agree with my conclusions about the role of the different types of stretching. However, I ask you to consider carefully the specificity principle of training and apply that to flexibility in the same way as you would to strength. For instance, no one would consider using only isometric contractions to develop strength in athletes. Instead, coaches try to devise strength exercises that are as specific as possible, both in terms of speed and mechanics, to the sports-specific condition. That said, why do so many people use only static stretches at the maximum ROM to develop flexibility for sport, which involves active motion through various ROMs depending on the movements?

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Raphael Brandon

The truth about stretching

A three year old study about stretching is being cited in many articles today, and the conclusions reached by some writers may be harmful to the muscle, ligaments and joints of your athletes.

Is stretching before exercise harmful?

Stretching before athletic training and general fitness improvement exercise is being made out to be a time waster, not needed, and even harmful. This is not true. In fact, there is a recent study that evaluates all the research on stretching, and the study concludes, “Due to the paucity (small number), heterogeneity (dissimilar study subjects) and poor quality of the available studies, no definitive conclusions can be drawn as to the value of stretching for reducing the risk of exercise related injury” (1).

Essentially, the researchers are saying that there are not enough quality studies to draw conclusions about this issue.

Study in question

The study that is generating all the hoopla was performed by the Kapooka Health Centre, New South Wales, Australia on 1,538 army recruits. It is a creditable study designed to show the occurrence of lower limb injury on a group of young army recruits. Despite what you may have heard about stretching before training, this is what the researchers actually reported, “A typical muscle stretching protocol performed during pre-exercise warm ups does not produce clinically meaningful reductions in risk of exercise related injury in army recruits. Fitness may be an important, modifiable risk factor (2).”

The statement, “Fitness may be an important, modifiable risk factor” is very important. It simply means that age, weight, and conditioning of the study subjects may be an important factor in preventing or facilitating the injuries experienced in this study.

Three years after the Kapooka study, another study involving military recruits was conducted and the researchers in this study show that pre-training static stretching can prevent injury involving muscle but not joint or bone injury. The researchers report, “Static stretching decreased the incidence of muscle related injuries but did not prevent bone or joint injuries” (3).

Appropriate conclusions

Based on the way some have written about this study, it is okay to run a 100 metre sprint full speed without stretching beforehand. Now, this may be possible for a small number of lean, young army recruits. However, does anyone believe that a powerful, muscled athlete or a middle-aged and older adult can go out and run a sprint, cold with no warm up and without increased risk of injury? Do not think so.

Use common sense... and the full body of research

Think about it; if an out of shape, untrained young army recruit performs high intensity exercise, he/she may get injured, pre-stretched or not. And this is why researchers evaluating all the research on stretching conclude, "No definitive conclusions can be drawn..."

In short, there needs to be a body of research based on age, weight, conditioning, and the study needs to be performed functionally for the specific sport and type of exercise before life changing conclusions are drawn.

The truth about stretching

New research shows that stretching can aid in the prevention of injury of stress fractures that plague distance runners. Researchers conclude, "Prevention of stress fractures is most effectively accomplished by increasing the level of exercise slowly, adequately warming up and stretching before exercise, and using cushioned insoles and appropriate footwear" [(4)].

Stretching offers many benefits. Researchers show that prolonged stretching (in the form of yoga) with moderate aerobic exercise and diet control will reduce cholesterol and significantly reverse hardening of the arteries (20% regression) in adults with proven coronary atherosclerotic disease.

After one year in a yoga program, participants lost weight, reduced cholesterol, and improved their exercise capacity [(5)].

Stretching offers many benefits, but there is an issue about the type of stretching and the timing of stretching before athletic competitions.

Use dynamic stretching before games and key practice sessions

There are two main types of stretching, static (holding a stretching exercise in one position without movement) and dynamic stretching, which means moving while stretching (arm swings, knee rotations, neck circles).

Researchers show that athletes should not perform prolonged static stretching before the big game or a key practice session because this slows muscle activation for around an hour afterwards [(6)]. Using dynamic stretching is a wise pre-competition strategy.

Static stretching builds flexibility and should be performed regularly, just not immediately before a big game or a key practice session.

Warming up prior to a high intensity, ballistic, athletic event is an absolute rule, never to be broken, and stretching can be combined (multi-tasked) as part of the warm up. The goal of the warm up is to get the blood flowing and raise body temperature (one degree) prior to athletic competitions and high intensity training. It is desirable to have the athlete's muscle, ligaments, and joints experience the functional range of motion required of the sport during the warm up.

Do static stretching with 30 second stretch-holds away from practice

Gains in flexibility are dependent on the 'duration' of stretch-hold position, and researchers show the best 'stretch-hold position' (for time spent) to increase flexibility is 30 seconds (7). 'Best' means optimal results for time spent. You can get positive results with 2 minute stretch-holds, but 30 seconds yields equal results.

This type of stretching is positive for athletes and adults of all ages. Researchers show in one study that longer hold stretching positions are of great benefit for adults over age 65, "Longer hold times during stretching of the hamstring muscles resulted in a greater rate of gains in range of motion (ROM) and a more sustained increase in ROM in elderly subjects." (8).

Adults aged 21 to 45 with tight hamstrings also get the best results from static stretching with 30 second stretch and hold positions. Researchers report that static stretching is two times more effective than dynamic range of motion (DROM) for this group of non competitive athletes. Researchers report, "The results of this study suggest that, although both static stretch and DROM (dynamic stretching) will increase hamstring flexibility, a 30 second static stretch was more effective than the newer technique, DROM, for enhancing flexibility" (9).

Keep in mind there are important lessons in these studies, but the studies apply to a specific age group (over 65, and ages 21 to 45) and a specific physical condition (tight hamstrings). If we apply the results of a study with these variables to young athletes, we may be wrong.

While it is reasonable to conclude (as I have for training purposes) that static stretching away from practice is an effective strategic for athletes with tight hamstrings, this study does not specifically prove that point. It is clearly a mistake to take the findings of one study and create an absolute fact. Look at the whole body of research about a topic before making a life changing training decision.

The take home about stretching

Use dynamic stretching and static stretching at the correct times in the training plan.

Dynamic stretching (arm swings, hip rotations and knee rotations) will aid in the pre-competition, pre-practice warm up process by increasing flexion in the joints and increasing body temperature. This method is preferred before athletic competition.

Static stretching can be used as part of a warm up for training. However, static stretching will slightly slow down athletes for an hour afterwards so examine training goals. The best way to improve overall flexibility is static stretching with 30 second stretch and holds performed away from events requiring peak performance.

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Phil Campbell M.S., M.A., FACHE

Dynamic stretching exercises

The following are examples of dynamic stretching and mobility exercises, which could form part of the warm up programme in a training session. Breathe easily whilst performing all the exercises.

Current research work detailed in *Medicine & Science in Sport and Exercise* 33(3), pp354-358 and *Journal of Strength and Conditioning Research*, vol 15 (1): 98-101 suggests that the use of dynamic stretches, slow controlled movements through the full range of motion, are the most appropriate exercises in a warm up routine.

The exercises

Neck mobility

Flexion/extension – tuck your chin into your chest, and then lift your chin upward as far as possible – 6 to 10 repetitions.

Lateral flexion – lower your left ear toward your left shoulder and then your right ear to your right shoulder – 6 to 10 repetitions.

Rotation – turn your chin laterally toward your left shoulder and then rotate it toward your right shoulder – 6 to 10 repetitions.

Shoulder circles

Stand tall, feet slightly wider than shoulder-width apart, knees slightly bent. Raise your right shoulder towards your right ear, take it backwards, down and then up again to the ear in a smooth action. Repeat with the other shoulder – 6 to 10 repetitions.

Arm swings

Stand tall, feet slightly wider than shoulder-width apart, knees slightly bent and keep the back straight at all times.

Overhead/down and back – swing both arms continuously to an overhead position and then forward, down, and backwards – 6 to 10 repetitions.

Side/front crossover – swing both arms out to your sides and then cross them in front of your chest – 6 to 10 repetitions.

Side bends

Stand tall with good posture, feet slightly wider than shoulder-width apart, knees slightly bent, and hands resting on hips. Lift your trunk up and away from your hips and bend smoothly first to one side, then the other, avoiding the tendency to lean either forwards or backwards. Repeat the whole sequence sixteen times with a slow rhythm, breathing out as you bend to the side and in as you return to the centre.

Hip circles and twists

Circles – with your hands on your hips and feet spread wider than your shoulders, make circles with your hips in a clockwise direction for 10 to 12 repetitions. Then repeat in a counter clockwise direction.

Twists – extend your arms out to your sides, and twist your torso and hips to the left, shifting your weight on to the left foot. Then twist your torso to the right while shifting your weight to the right foot. 10 to 12 reps on each side.

Half squat

Stand tall with good posture holding your hands out in front of you for balance. Now bend at the knees until your thighs are parallel with the floor. Keep your back long throughout the movement, and look straight ahead. Make sure that your knees always point in the same direction as your toes. Once at your lowest point, fully straighten your legs to return to your starting position. Repeat the exercise sixteen times with a smooth, controlled rhythm. Breathe in as you descend, and out as you rise.

Leg swings

Flexion/extension – stand sideways onto the wall, weight on your left leg and your right hand on the wall for balance; swing your right leg forward and backward – 10 to 12 repetitions on each leg.

Cross-body flexion/abduction – leaning slightly forward with both hands on a wall and your weight on your left leg, swing your right leg to the left in front of your body, pointing your toes upwards as your foot reaches its furthest point of motion. Then swing the right leg back to the right as far as comfortable, again pointing your toes up as your foot reaches its final point of movement – 10 to 12 repetitions on each leg.

Lunges

Standing tall both feet together (starting position). Keeping the back straight lunge forward with the right leg approx. 1 to 1.5 metres. The right thigh should be parallel with the ground and the right lower leg vertical. Spring back to the starting position. Repeat with the left leg – 12 to 16 repetitions on each leg.

Ankle bounce

Double leg bounce – leaning forward with your hands on the wall and your weight on your toes, raise and lower both heels rapidly (bounce). Each time, lift your heels one to two inches from the ground while maintaining ground contact with the balls of your feet. 12 to 16 repetitions.

Single leg bounce – lean forward with your hands on the wall. With all your weight on your left foot, raise the right knee forward while pushing the left heel towards the ground. Then lower the right foot to the floor while raising the left heel one or two inches. Repeat in a rapid, bouncy fashion. 12 to 16 repetitions on each leg.

Remember

The dynamic exercises you incorporate into your warm up program should be appropriate to the movements you would experience in your sport/event.

Brian Mackenzie

Static stretching exercises

The following are examples of general static stretching and mobility exercises, which could form part of the cool down programme at the end of a training session. In all exercises breathe easily whilst performing them and hold the static stretches for 20 to 30 seconds.

Current research work detailed in *Medicine & Science in Sport and Exercise* 33(3), pp354-358 and *Journal of Strength and Conditioning Research*, vol 15 (1): 98-101 suggests that the use of static stretches are more appropriate for the cool down.

The exercises

Chest stretch

Stand tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent. Hold your arms out to the side, parallel with the ground and the palms of the hand facing forward. Stretch the arms back as far as possible. You should feel the stretch across your chest.

Biceps stretch

Stand tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent. Hold your arms out to the side, parallel with the ground and the palms of the hand facing forward. Rotate the hands so the palms face to the rear. Stretch the arms back as far as possible. You should feel the stretch across your chest and in the biceps.

Upper back stretch

Stand tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent. Interlock your fingers and push your hands as far away from your chest as possible, allowing your upper back to relax. You should feel the stretch between your shoulder blades.

Shoulder stretch

Stand tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent. Place your right arm, parallel with the ground across the front of your chest. Bend the left arm up and use the left forearm to ease the right arm closer to you chest. You will feel the stretch in the shoulder. Repeat with the other arm.

Shoulder and triceps stretch

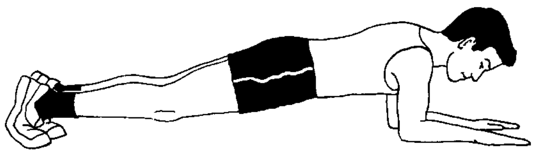
Stand tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent. Place both hands above your head and then slide both of your hands down the middle of your spine. You will feel the stretch in the shoulders and the triceps.

Side bends

Stand tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent, hands resting on the hips. Bend slowly to one side, come back to the vertical position and then bend to the other side. Do not lean forwards or backwards.

Abdominal and lower back muscles

Lie face down on the ground in a prone position. Lift your body off the ground so that you are supported only by your forearms and toes. The elbows should be on the ground and should be almost directly below your shoulders. Your forearms and hands should be resting on the ground, pointed straight ahead, toes and feet should be shoulder-width apart and your head in line with your spine.



Starting position

- Contract your gluteus (bum) muscles gently. Hold for 10 seconds
- Lift your right arm off the ground, straighten it and point it straight ahead, holding it in the air for 10 seconds
- Return to the starting position
- Lift your left arm off the ground, straighten it and point it straight ahead, holding it in the air for 10 seconds
- Return to starting position
- Lift your right leg off the ground and hold it there for 10 seconds (keep back straight)
- Return to starting position
- Lift your left leg off the ground and hold it there for10 seconds (keep back straight)

- Return to starting position
- Lift your right arm and left leg simultaneously and hold them in position for 10 seconds
- Return to starting position
- Lift your left arm and right leg simultaneously and hold them in position for 10 seconds
- Return to the starting position.

Hamstring stretch

Sit on the ground with both legs straight out in front of you. Bend the left leg and place the sole of the left foot alongside the knee of the right leg. Allow the left leg to lie relaxed on the ground. Bend forward keeping the back straight. You will feel the stretch in the hamstring of the right leg. Repeat with the other leg.

Calf stretch

Stand tall with one leg in front of the other, hands flat and at shoulder height against a wall. Ease your back leg further away from the wall, keeping it straight and press the heel firmly into the floor. Keep your hips facing the wall and the rear leg and spine in a straight line. You will feel the stretch in the calf of the rear leg. Repeat with the other leg.

Hip and thigh stretch

Stand tall with your feet approximately two shoulder-widths apart. Turn the feet and face to the right. Bend the right leg so that the right thigh is parallel with the ground and the right lower leg is vertical. Gradually lower the body. Keep your back straight and use the arms to balance. You will feel the stretch along the front of the left thigh and along the hamstrings of the right leg. Repeat by turning and facing to the left.

Adductor stretch

Stand tall with your feet approximately two shoulder-widths apart. Bend the right leg and lower the body. Keep your back straight and use the arms to balance. You will feel the stretch in the left leg adductor. Repeat with the left leg.

Groin stretch

Sit with tall posture. Ease both of your feet up towards your body and place the soles of your feet together, allowing your knees to come up and out to the side. Resting your hands on your lower legs or ankles and ease both knees towards the ground. You will feel the stretch along the inside of your thighs and groin.

Front of trunk stretch

Lie face down on the floor, fully outstretched. Bring your hands to the sides of your shoulders and ease your chest off the floor, keeping your hips firmly pressed into the ground. You will feel the stretch in the front of the trunk

Iliotibial band stretch

Sitting tall with legs stretched out in front of you. Bend the right knee and place the right foot on the ground to the left side of the left knee. Turn your shoulders so that you are facing to the right. Using your left arm against your right knee help ease you further round. Use your right arm on the floor for support. You will feel the stretch along the length of the spine and in the muscles around the right hip.

Quadriceps stretch

Lie face down on the floor, resting your forehead on your right hand. Press your hips firmly into the floor and bring your left foot up towards your buttocks. Take hold of the left foot with the left hand and ease the foot closer to you buttocks. Repeat with the right leg. You will feel the stretch along the front of the thigh.

Remember

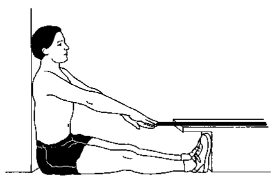
These stretches must be effective, safe and stable in terms of their mechanics and used to ensure a normal range of motion in all muscle groups plus any sport event-specific range of motions. The aim is to relax the muscles and facilitate an improvement in maximum range of motion.

Brian Mackenzie

Static flexibility tests

Testing and measurement are the means of collecting information upon which subsequent performance evaluations and decisions are made but in the analysis we need to bear in mind the factors that may influence the results. Here we will look at five tests in all – hip & trunk, shoulder & wrist, trunk & neck, shoulder & ankle.

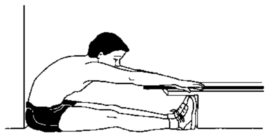
Test 1 – hip and trunk



Starting position

- Sit on the floor with the back and head against a wall, legs fully extended with the bottom of the feet against the sit-and-reach box
- Place the hands on top of each other, stretching the arms forward while keeping the head and back against the wall

- Measure the distance from the fingertips to the box edge with a ruler. This becomes zero or starting point.



Movement

- Slowly bend and reach forward as far as possible sliding the fingers along the ruler
- Hold the final position for 2 seconds
- Record the distance reached to the nearest 1/10 inch.

Repeat the test 3 times and note the best distance.

Performance Rating

Tables adapted from Johnson B.L. & Nelson J.K. 'Practical Measurements for Evaluation in PE' 4th Ed. 1986

Age <36

Rating	Men	Women
Excellent	>17.9	>17.9
Good	17.0 – 17.9	16.7 – 17.9
Average	15.8 – 16.9	16.2 – 16.6
Fair	15.0 – 15.7	15.8 – 16.1
Poor	<15.0	<15.4

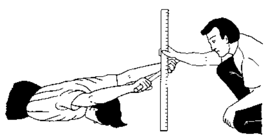
Age 36 to 49

Rating	Men	Women
Excellent	>16.1	>17.4
Good	14.6 – 16.1	16.2 – 17.4
Average	13.9 – 14.5	15.2 – 16.1
Fair	13.4 – 13.8	14.5 – 15.1
Poor	<13.4	<14.5

Test 2 – shoulder & wrist

Starting position

- Lay prone on the floor with the arms fully extended holding a stick.



Movement

- Raise the stick as high as possible, keeping the nose on the ground
- Measure the vertical distance the stick rises from the floor to the nearest half-inch
- Repeat the test 3 times and record the best distance
- Measure the arm length from the acromial extremity to the tip of the longest finger
- Subtract the best score from the arm length.

Performance rating

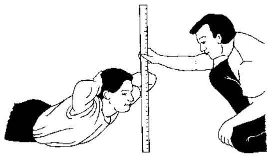
Table adapted from Johnson B.L. & Nelson J.K. Practical Measurements for Evaluation in PE 4th Ed. 1986.

Rating	Men	Women
Excellent	>12.50	>11.75
Good	12.50 – 11.49	11.75 – 10.74
Average	11.50 – 8.24	10.75 – 7.49
Fair	8.25 – 6.00	7.50 – 5.50
Poor	<6.0	<5.50

Test 3 – trunk and neck

Starting position

- Lay prone on the floor with hands clasped at the side of the head.



Movement

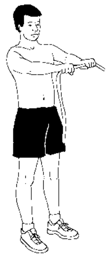
- Raise the trunk as high as possible whilst keeping the hips in contact with the ground
- An assistant can hold the feet down
- Record the vertical distance, to the nearest 1/4 inch, from the tip of the nose to the ground
- Repeat the test 3 times and record the best distance.

Performance rating

Table adapted from Johnson B.L. & Nelson J.K. 'Practical Measurements for Evaluation in PE' 4th Ed. 1986.

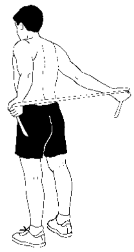
Rating	Men	Women
Excellent	>10.00	>9.75
Good	10.00 – 7.99	9.75 – 7.74
Average	8.00 – 5.99	7.75 – 5.74
Fair	6.00 – 3.00	5.75 – 2.00
Poor	<3.00	<2.00

Test 4 – shoulder



Starting position

- Grasp one end of the rope with the left hand
- Four inches away grasp the rope with the right hand.



Movement

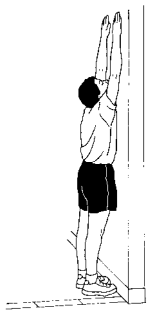
- Extend both arms in front of the chest and rotate the arms overhead and behind the neck until the rope touches the back
- As resistance occurs allow the right hand to slide along the rope
- Measure the distance between the two thumbs – to the nearest 1/4 inch
- Measure shoulder-width from deltoid to deltoid – to the nearest 1/4 inch
- Subtract the shoulder-width distance from the thumb distance
- Repeat the test 3 times and record the best distance.

Performance Rating

Table adapted from Johnson B.L. & Nelson J.K. 'Practical Measurements for Evaluation in PE' 4th Ed. 1986.

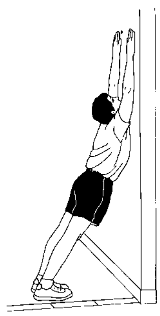
Rating	Men	Women
Excellent	<7.00	<5.00
Good	11.50 – 7.00	9.75 – 5.00
Average	14.50 – 11.49	13.00 – 9.74
Fair	19.75 – 14.49	17.75 – 12.99
Poor	>19.75	>17.75

Test 5 – ankle



Starting position

- Stand facing a wall
- Feet flat on the ground toes touching the wall
- Lean into the wall.



Movement

- Slowly slide the feet back from the wall as far as possible
- Keep the feet flat on the ground, body and knees fully extended and the chest in contact with the wall
- Measure the distance between the toe line and the wall – to the nearest 1/4 inch
- Repeat the test 3 times and record the best distance.

Performance rating

Table adapted from Johnson B.L. & Nelson J.K. 'Practical Measurements for Evaluation in PE' 4th Ed. 1986

Rating	Men	Women
Excellent	>35.50	>32.00
Good	35.00 – 32.51	32.00 – 30.51
Average	32.50 – 29.51	30.50 – 26.51
Fair	29.50 – 26.50	26.50 – 24.25
Poor	<26.50	<24.25

Brian Mackenzie

Module 6

Local Muscle Endurance

Local muscle endurance

Local muscle endurance is a single muscle's ability to continue working, *eg* whilst cycling and rowing.

All muscle training falls into three categories: isotonic training, isometric training and isokinetic training.

In isotonic contractions the muscle contracts and shortens, giving movement. Nearly all the training you do is isotonic.

In isometric contractions the muscle contracts but does not shorten, giving no movement.

In isokinetic contractions the muscle contracts and shortens at constant speed. An isotonic contraction is different to an isokinetic contraction because it is usually slowest at the start and increases in speed as the movement continues. For isokinetic training you need special equipment that detects when a muscle is speeding up, and increases the load to slow it down again so as to maintain a constant speed of movement.

Overview of the articles in this section

- Joe Dunbar in his article 'Pedal your way to success' explains the demands of the cycle racing and how cyclist should plan their training
- Dawn Hunter explains how Triathletes can increase their running speed in her article 'Tri speed development'

- Brian Mackenzie in his article 'The ups and downs of hill training' explains the benefits of hill training and the type of training you can carry out on those hills
- Walt Reynolds explains how to design a circuit training session to meet your needs in his article 'An excellent way to build local muscle endurance'
- Brian Mackenzie in his article 'Critical swim speed test' provides a test to determine the appropriate target time for each repetition of a swimmer's aerobic training session.

The articles in this section are applicable to most sports.

Pedal your way to success

The Tour de France, with its harsh regime of hundreds of miles of race cycling on consecutive days, must represent one of the peak challenges in sport. If you are a keen cyclist, however, it is unlikely that you are training for such a feat of endurance. More commonly, you will be doing road races at the weekend and occasional time trials, cycling during triathlons or you may even venture onto the track.

Demands of the sport

Racing cyclists usually possess high levels of aerobic endurance, since most road races last well over an hour. This means that if you are going to succeed in endurance cycling, you need a well developed oxygen transport system, which often gives rise to high VO_2max values. Elite cyclists have been measured to be able to pick up, transport and utilise seven litres of oxygen per minute. A high VO_2max is not enough, however, to guarantee you success in cycling events. Due to their long duration, aerobic efficiency is also a vital requirement. As with marathon runners, you must be able to work at a high percentage of your VO_2max without accumulating lactate. Once it does start to accumulate, indicating a greater contribution of anaerobic metabolism to the energy supply, you must reduce the workload in order to avoid premature fatigue.

The high levels of aerobic conditioning needed to give you this aerobic efficiency also hold another advantage, the ability to use a greater proportion of fat rather than carbohydrate for muscle fuel. Aerobic conditioning enhances the ability to use abundant fats while exercising, thus sparing your limited precious carbohydrate, stored in the liver and muscles as glycogen.

Nevertheless, the ability to use anaerobic metabolism is another training aspect that must not be neglected. If your opponent, or rival, puts in a burst of speed that you need to cover, you may well have to dig deep and rely on a greater contribution of anaerobic metabolism to the energy supply. This may also be the case if you encounter a tough hill. In other words, low intensity aerobic work alone is not enough if you want to succeed as a cyclist.

Sheer muscle strength is another essential requirement. Cycling, after all, is a power endurance activity, so if you have a high level of muscular strength, you will need to use a smaller percentage of your maximum strength to maintain the same workload.

Phases of training

As with many sports, the main competition period occurs in the summer. The season can stretch for as long as 30 weeks, so it is important to plan your training to suit your racing requirements. Since it is not realistic to maintain a peak over several months, you may have to choose the part of the season that is most important for you and peak then, or you can plan two separate peaks. This will depend on your own racing goals. Whether your aim is to win the national championships, or simply to perform well in a couple of league races, you must try to be single minded and not expect to race well for successive weeks before and after the peak. It is more realistic to use additional races as hard training, which may come in the middle of hard weeks, so that when you ease up on the training load, your performance will be boosted for the competitions that matter.

The pattern of your year will be greater mileage and endurance work during the winter, which for safety reasons may be carried out indoors on rollers. During the spring, you may want to change the emphasis to more quality work, with less training volume, bringing you towards your competition period, where the emphasis is on sharpening with a tapered volume. It is not sensible to be training hard during the weeks when you want to race well.

The training week

Throughout the year you should always train the whole spectrum of fitness; it is the proportions that change as the months go by. You need to perform long steady state rides at a low intensity to encourage and improve your ability to metabolise fats. These rides will last several hours. You will do more of them during the winter but they should be kept up throughout the year.

Threshold training will help to increase the speed at which the anaerobic threshold occurs, and should thus elevate your racing speed. These rides will typically last around 30 minutes, outside of warm up and warm down. High intensity training may well help to raise your VO_2max and increase your ability to tolerate the acidic conditions that prevail in fast bursts or up a hill. You would normally perform these sessions in intervals, *eg* 10 x 1 minute hard, split by a minute's recovery.

Hill training is another way to help your body cope with the demands of sudden bursts. You can simply cycle hard up a hill and free wheel down before you repeat. Alternatively, you can find a hilly circuit and perform reps around this, putting in greater efforts uphill and recovering going down. This training will help to improve your power and strength and so too will regular workouts in the weights room. Here work on the hamstrings, calves and quadriceps is particularly important.

How you put all this together is a matter of individual preference.

Joe Dunbar

Tri speed development

The aim of many athletes is to increase their speed in their chosen discipline. Many articles cover the different ways in which this can be achieved and this article aims to add another viewpoint to the melting pot.

The information covered here has been applied to the three disciplines of triathlon (swimming, cycling and running) with apparently equal success. However, running is under consideration here as swimming and cycling are more technique based.

The triathletes with whom this method has worked mostly race sprint (750m swim, 20k bike, and 5k run) and standard (1500m swim, 40k bike, and 10k run) distances, so the run distances over which the speed has increased are 5k and 10k. Whether this method would work for other distances is not known.

Time is a big factor when training for triathlon, particularly when a full-time job is also involved, which was the case for all the athletes. This requires that any speed development programme be designed in such a way as to minimise the number of sessions required and maximise the benefits from those sessions. In order to fit sessions in round other commitments it is also important that they are not too long.

Interval work, where the athlete works at a particular intensity for a particular length of time, is commonly believed to be one of the best ways to increase speed and the methods used here are interval sessions. The key factors in any interval work are:

- length of the interval
- length of the recovery
- the number of intervals
- the speed or intensity of the interval.

This article will show how these factors were manipulated over periodised programmes in order to improve an athlete's speed, without over challenging them. Speed development can be worked on throughout all the phases of a periodised programme. If the phases to be considered are base, preparation and competition, then the speed development will focus on speed strength in the base phase, standard speed in the preparation phase, and pure speed in the competition phase. Again, the variables remain as: number of intervals, length of the interval, length of recovery, and the speed or intensity of the interval.

Base phase	Preparation phase	Competition phase
Speed strength	Standard speed	Pure speed
length of interval; length of recovery; number of intervals; speed/intensity of the interval		

The athletes all had previous 10k times which the speed of the intervals could be calculated from. However, if there is no 10k time available, there are various ways to arrive at a point at which interval calculations can be made.

1) Following a warm up, athletes could run a time trial – a set distance (which could be a full 10k if desired) where the time taken to complete the distance is taken. This time, can be extrapolated up to a likely 10k time if necessary using calculators on the internet (for example, try www.brianmac.demon.co.uk/racecalc.htm)

2) Failing either of these, and assuming that the athlete's goal is realistic, then it would be possible to work out target times based on the 10k time they would like to achieve, *ie* their goal time. However, this method should be treated with caution. In the event of the athletes goal not being SMART (specific, measurable, achievable, realistic and time-framed), the intervals calculated would be too difficult, not achievable and lead to a sense of failure on behalf of both athlete and coach.

Speed strength

When looking at the base phase and the building of speed strength, the key components will be high repetitions, medium workload and low rest. Over a 12-week programme of speed development for 10k running, this would cover 400m, 800m, and 1-mile repetitions with one session of a combination of distances in a pyramid format over the 4-week base phase of the 12-week programme. The repetitions would be 12 for 400m, 8 for 800m, and 6 for 1 mile. The rest interval would be 60 seconds for all distances and the intensity would be set at 98% of the current race pace for 10k, *ie* 2% faster than race pace.

So, for example, a previous best of 45 minutes for 10k would lead to (rounded up) intervals of:

400	1:46
800	3:36
1 mile	7:03

Standard speed

In the preparation phase the distances would be kept the same, but the number of repetitions changes to 10 for 400m, 6 for 800m, and 4 for one mile. The intensity is increased to 96% of 10k race pace, *ie* 4% faster than 10k race pace and to reflect this increase in intensity the recovery interval increases to 3 minutes for all distances.

So, to take the 45 minute 10k example again the (rounded up) intervals would be:

400	1:44
800	3:28
1 mile	6:55

Pure speed

The competition phase is where the intensity increases another notch, the repetitions come down and the recovery increases again. So the repetitions would be 8 for 400m, 4 for 800m and 3 for one mile with 5 minutes recovery between each. These intervals are run at 95% of 10k pace, so 5% faster than race pace.

If the same example is used the (rounded up) intervals become:

400	1:43
800	3:25
1 mile	6:50

Pyramid sessions

The last week of any 4-week phase is an opportunity to play around with the distances. The same principles apply in terms of intensity percentage and length of recovery, but extra distances can be added, for example, one week the session might be 100, 200, 400, 800, 1200, 800, 400, 200, 100, another week it might be 400, 800, 1200, 1 mile, 1200, 800, 400. This makes things a bit more interesting for the athlete and is actually a hard session in its own right, particularly if the descent down the pyramid is done with a negative split!

Variations

Not everyone has access to a track. It is important to be able to measure improvement in some way, so some standard route should be found for this purpose. Otherwise, the calculations remain the same, but the focus is on running hard for the amount of time set. So, for pure speed medium intervals, the athlete would run for 3:25 as fast as they can for that length of time. If the same route is run as an out and back, they should (barring hills, etc) get back to where they started at the end of each second repetition. The pace could also be determined by heart rate, so for example, the athlete could run at 85% of max heart rate for the required length of time – many heart rate monitors can be programmed to beep if the heart rate fluctuates a certain amount of beats away from the target.

Heart rate can also be used for the recovery intervals. If the heart rate is taken immediately following the warm up, this rate can be used as the point at which the next interval is run. So, for example, if at the end of the warm up an athlete's heart rate is 120, then after each interval, when the heart rate has dropped to 120, then the next interval should start.

Specificity

As the whole basis of the interval calculation is based upon the athlete's actual 10k time, it is specific to them. As their pace increases, their potential 10k time can be extrapolated from for example a 1-mile time trial every 4 weeks and any change in the resulting 10k time can be reflected in the calculations. This way, the programme progresses as fast as the athlete does.

Success

It is difficult to quantify the success of this method of speed development in actual races as it has only been in use for just over 12 months and for varying periods during that time with different athletes (based upon specific goals). All the athletes are posting considerably faster run times than before with improvements of between 3 and 5 minutes on their 10k times in previous races. However this needs to be viewed with caution, as the triathlon run section is often variable in true distance, is frequently on varied terrain and it is difficult to compare one triathlon 10k with another. In another 12 months, assuming the same athletes do the same races, it will be easier to see, but at the moment as some of them are moving from sprint, through to standard and even on to half ironman and ironman distance it is difficult to truly quantify. Importantly, the athletes feel they are running well and they are pleased with their improvements to date. Obviously, as a coach I am constantly on the look out in case there is something that will benefit my athletes further.

Dawn Hunter

The ups and downs of hill training

This ergogenic aid has a strengthening effect as well as boosting your athlete's power and is ideal for those athletes who depend on high running speeds, *eg* football, rugby, basketball, cricket players and even runners.

So what is it? Answer: Hills.

How to approach uphill running

The technique to aim for is a 'bouncy' style where the athlete has a good knee lift and maximum range of movement in the ankle. They should aim to drive hard, pushing upwards with their toes, flexing their ankle as much as possible, landing on the front part of the foot and then letting the heel come down below the level of the toes as the weight is taken. This stretches the calf muscles upwards and downwards as much as possible and applies resistance which overtime will improve their power and elasticity. The athlete should look straight ahead as they run (not at their feet) and ensure their neck, shoulders and arms are free of tension. Many experts believe that the 'bouncy' action is more important than the speed at which the athlete runs up the hills. For the athlete, when competing in their sport/event, it can mean higher running speeds and shorter foot strike times.

Benefits of hill training

Hill training offers the following benefits:

- helps develop power and muscle elasticity
- improves stride frequency and length
- develops co-ordination, encouraging the proper use of arm action during the driving phase and feet in the support phase
- develops control and stabilisation as well as improved speed (downhill running)
- promotes strength endurance
- develops maximum speed and strength (short hills)
- improves lactate tolerance (mixed hills).

Types of hill training

Not all hills are the same (*eg* inclination and length) and the benefits of short, medium and long hills are quite different and can be used at different times of the year.

Short hills

A short hill is one which takes no more that 30 seconds to run up and has an inclination between 5 and 15^{o} gradient. The athlete's energy source on short hills is entirely anaerobic. The athlete should focus on a running technique which has vigorous arm drive and high knee lift, with the hips kept high, so that they are 'running tall', not leaning forwards.

The session is anaerobic so the recovery time can be long, a walk back down the hill, or a slow jog of 60 to 90 seconds. The total volume will depend on the fitness of the athlete and the reason for doing it. A sprinter looking for strength might do 10 repetitions of 15 seconds duration up a steep slope with a long recovery where as a distance runner who is trying to improve sprinting speed might do 30 repetitions of 15 seconds duration.

Short hills of 5 to 10 second duration will help improve the adenosine triphosphate and phosphate creatine (ATP + PC) energy system and hills of 15 to 30 second duration will help develop the ATP + PC + muscle glycogen energy system. Example of short hill sessions:

- 8 to 10 repetitions over 50 metres (sprinters and hurdlers)
- 8 to 10 repetitions over 40 metres (jumpers and throwers)
- 8 to 10 repetitions over 150 metres (middle distance athletes)
- 8 to 10 repetitions over 200 metres (long distance athletes).

Medium hills

A medium hill is one which takes between 30 to 90 seconds to run up. This length of hill is a good distance for the middle-distance runner, because it combines the benefits of the short hills with the stresses on local muscular endurance and tolerance of lactic acid. Use a hill as steep as one-in-six to one-in-ten, so that you can run at something near race pace. The energy source is both aerobic and anaerobic and the athlete will experience the build up in blood lactate as they go further up the hill.

Although the session will usually be quite fast and competitive, it is important that style is emphasised. Shooting up the hill with a short stride and forward lean may be the best way to get up in a race, but in training we are trying to develop particular qualities. It is better, therefore, to go for a longer stride and higher knee lift: running tall with the hips pushed forwards, keeping the back upright. Again, the volume of the session depends on the individual.

With a group of youngsters you can do six to eight runs of 45 seconds, followed by some 10 second sprints on a steeper hill. With top class senior runners you can do 12 to 15 runs of about 70 seconds, so that it is the equivalent of an interval training session on the track. A good practice is to increase the number by one or two each time the session comes around, while trying to run them at about the same pace. The recovery is a slow jog back to the bottom, and when the times start falling much below those of the first few runs, it is time to stop.

Long hills

A long hill is one which takes from 90 seconds to 3 minutes plus. Here most of the energy comes from aerobic sources, but if parts of the hill are steep and they are running them hard, there will still be an accumulation of blood lactate. There will be local muscular fatigue in the leg muscles, and possibly in the abdominal muscles too, but the main limiting factor will be the athlete's cardiovascular system.

These long hills can be used in two ways:

- as a hard aerobic training session during the pre-competition season
- as a hard time-trial session in the early part of the competition period.

As these hill sessions are aerobic, the athlete will not use as much power per stride as the shorter hills, and so perhaps would not be used by middle-distance runners, except for one or two time-trial runs. They are particularly good for the cross country or road runner who is running distances of 10,000m and upwards. A session of, say 8 x 3 minutes, with a run back of 4 or 5 minutes will make a good hard workout.

Downhill running

Many runners develop muscle soreness after strenuous workouts or races. Research (Muscle function after exercise induced muscle damage and rapid adaptation, *Medicine and Science in Sports and Exercise*, vol 24 (5), pp 512-520 1992) has shown that the muscle pain and loss of strength can be minimised if runners undertake regular sessions of eccentric training. For runners this would involve downhill running as it will put the muscles in the front of the leg under intense eccentric duress. A single downhill session (6 to 10 downhill runs over 300 metres) on a 300 to 400 metre hill with an inclination of 10 to 15° should provide protection against muscle pain and loss of strength for at least six weeks.

Injury prevention

To reduce the possibility of injury the athlete requires a good solid base of general strength and general endurance before undertaking hill work. With all hill sessions it is important to warm up before and to cool down after the hill session.

Brian Mackenzie

An excellent way to build local muscle endurance

During the past few years, endurance athletes in a number of sports have added resistance exercises to their training programs in an effort to boost their muscle power and decrease their risk of injury. Scientific studies have linked resistance training with a reduced rate of injury in athletes. This is probably because resistance work fortifies leg muscles and strengthens 'weak links' in athletes' bodies, including the often injured hamstrings and shin muscles, as well as abdominal and low back muscles.

Resistance work can also improve tendon and ligament strength and increase bone density, effects which should help to lower injury rates. In addition, resistance workouts heighten body awareness, upgrade co-ordination, reduce body fat levels, and improve self esteem, all of which can contribute to improved performance during competition.

For athletes, the general preparation period before the beginning of actual competitions is an ideal time to initiate a resistance training program. A 4 to 8 week period of sound resistance training helps to develop a nice foundation of suppleness (mobility), strength, and stamina (endurance), to which athletes can add speed and racing skill just before the competitive season begins.

'Circuit training' is an excellent way to simultaneously build strength and stamina. The circuit training format utilises a group of strength exercises (usually 6 to 10 or more) that are completed sequentially (one exercise after another). Each exercise is performed for a specified number of repetitions or for a prescribed time period before moving on to the next exercise. The exercises within each circuit are separated by brief, timed rest intervals, and each circuit is separated by a longer rest period. The total number of circuits performed during a training session may vary from 2 to 6 depending on your training level (beginner, intermediate, or advanced), your period of training (preparation or competition), and your primary training objective (You may be developing total work capacity, boosting your power, or engaging in 'active rest,' for example.)

I have designed this special circuit training with the following objectives in mind:

1) The circuit work will increase your general work capacity by improving your ability to tolerate increasing levels of muscular fatigue (stamina improvement)
2) Over time, the circuit training will have shorter and shorter rest intervals between exercises, thus maintaining elevated heart rates during the circuit workouts and helping you to upgrade your cardio-respiratory capacity (stamina improvement)
3) Circuit efforts will enhance your overall body strength, including the strength and resiliency of muscles, tendons, and ligaments, the integrity of your joints, and the strength and density of your supporting bone structures (strength improvement)

4) The circuits will improve your movement skill and body awareness, because you will perform exercises that utilise body weight as the primary form of resistance (skill improvement)
5) The circuit program will increase your lean muscle mass by a moderate amount and decrease your body fat levels through high levels of energy expenditure (body composition improvement).

The basic training circuit: recommendations

Your basic training circuit can easily be combined with the mobility training to form a well rounded training session. A full mobility plus circuit workout, including warm up, mobility training, circuit work, and a 10 minute cool down can be completed in about an hour or less.

Is that too much time for the busy athlete? No. For one thing, you only need to complete the overall workout twice weekly during your base conditioning period. In addition, the payoffs from circuit training are great. Whether you are a cyclist, a race walker, a runner, a rugby player, a swimmer, or a participant in racket sports, you will improve your strength, mobility and stamina through circuit training. As a result, you will move much more powerfully as you take part in your sport.

Bear in mind, though, that for best results the circuit training sessions should not be performed on consecutive days. If you are carrying out other intensive training on the same day as the circuit work, undertake the intensive work before the circuit training, since fatigue levels from the circuit might well interfere with training intended to develop speed, power, or event-specific endurance. Better yet, carry out circuit training on days during which other training is of low intensity. Do not do your circuit training on a rest day, however; rest really means rest.

Here is your sequential format for each circuit:

1) Total body exercise
2) Upper body exercise
3) Lower body exercise
4) Core/trunk exercise
5) Total body exercise
6) Upper body exercise
7) Lower body exercise
8) Core/trunk exercise.

Notice that each part of the body is emphasised twice during each circuit. The amount of rest between exercises and the total rest between circuits is described opposite.

The basic training circuits: how long to work and rest for each exercise			
Exercise	Moderate Circuit	Moderate/Hard Circuit	Hard Circuit
	(work/rest ratio)	(work/rest times)	(work/rest)
1. 4 count squat thrusts	15 sec:15 sec	20 sec:20 sec	30 sec:30 sec
2. push-ups	15 sec:15 sec	20 sec:20 sec	30 sec:30 sec
3. scissor step ups	15 sec:15 sec	20 sec:20 sec	30 sec:30 sec
4. abdominal sit backs	15 sec:15 sec	20 sec:20 sec	30 sec:30 sec
5. squats to presses	15 sec:15 sec	20 sec:20 sec	30 sec:30 sec
6. body weight rows	15 sec:15 sec	20 sec:20 sec	30 sec:30 sec
7. one leg squats	10 sec for each leg: 20 sec rest	15 sec for each leg: 30 sec rest	20 sec for each leg 30 sec rest
8. low back stabilisers	15 sec:15 sec	20 sec:20 sec	30 sec:30 sec
Rest between circuits	2 minutes	2 minutes	3 minutes

Please perform the exercises in the order indicated, starting with 4 count squat thrusts and then proceeding to push-ups, etc. When you finish each circuit by completing the low back stabilisers, rest for the indicated amount of time and then cycle back to the 4 count squat thrusts.

Note that work/rest times vary for the three different types of circuits – moderate, moderate/hard and hard.

Circuit training progression: making your circuit training more difficult over time			
Week	Circuit type	Number of circuits/workout	Total work (seconds)
1	moderate	2	250
2	moderate/hard	2	340
3	hard	2	500
4	moderate	3	375
5	moderate/hard	3	510
6	moderate/hard	4	680
7	hard	3	750
8	moderate/hard	3	510

The eight exercises in your circuit

For each circuit, do the following exercises:

Four count squat thrusts

Stand with your arms held at your sides, and then squat down, placing both hands in front of you on the floor. With arms straight and your weight resting on both hands, quickly extend both legs backward (hop backward), ending in a front support position. Return legs forward (hop forward) ending in a low squat position with hands on the floor. Finally, jump into the air and return to a standing position. Repeat each of these four steps, in order, to a rhythmic 1-2-3-4 count, without pausing between counts or repetitions.

How will this exercise benefit you?

The high degree of amplitude (joint motion) at your hips and knees, combined with the resistance provided by your body weight, will develop strength and mobility in your knee and hip joints, important for high speed movement. The front support position develops stability and strength in the upper trunk, abdominal, and pelvic regions, strength that is necessary to control torso movements during the running stride or when you strike a ball. The jump added to the exercise as you return to a standing position greatly increases your cardiac demand, hikes the power of your leg muscles, and increases the impact forces (upon landing) as well, fortifying the bones in your legs and feet. Use caution, though; perform the movements on a gym floor or grass, not on concrete.

Push-ups

Start in the front support position with your hands and toes on the floor and trunk, hips, and legs extended. Bend your arms and lower your chest to the floor. Then push your body upward as you straighten your arms, returning to the front support position. Repeat this action rhythmically and continuously without stopping for the allotted time.

How does this benefit you?

Push-ups are well known for increasing upper body strength, but their value in developing abdominal and hip flexor stability is often ignored. This improved stability helps to control hip, trunk, and shoulder movements as you move quickly and also promotes balance between the upper and lower body.

Scissor step ups

Use a step or bench which is approximately mid shin to knee height. Put your left foot on the step, with your right foot on the floor and your arms at your sides. Then push down with your left leg and drive your body upward rapidly, switching support (hopping) from left foot to right foot as your body reaches its maximal vertical height. With your right foot supporting your body, lower the left foot to the floor rapidly but under control. Repeat this action continuously, back and forth from foot to foot, without pausing at the top or bottom positions.

How can this help you?

The scissor step up develops leg strength, power, and dynamic balance control (co-ordination), without which you cannot move quickly, whether it is from one end of the football pitch to the other, from the baseline to the net on a tennis court, or from the start to the finish of a 10k race. Cardiovascular benefits of this exercise can be increased by speeding up your stepping cadence or by increasing the height of the step. Step heightening also enhances leg muscle power and improves mobility of the hip and knee joints.

Abdominal sit backs

For this exercise, use a step, bench, or chair which does not have a vertical, support for your back. Sit with your legs bent and your arms extended in front of you, and then recline your trunk backward at the hips by about 45°. That is your starting point for the exercise. To do the sit backs, raise both arms simultaneously overhead while maintaining tight abdominal muscles and a straight chest. Then simply return your arms to the extended position in front of you, without moving your trunk or legs. Repeat this back and forth arm action in a smooth, continuous fashion without pausing at any point during the movement.

How will this exercise benefit you?

The increased abdominal stability gained from sit backs carries over to improved posture and better core stability as you run. A strong pelvic girdle and trunk provide the anchor point for a strong pair of legs, allowing you to use your legs in a maximally powerful manner during quick sprints or during sustained, vigorous running.

Squats to presses

Use two dumbbells, each weighing approximately 10% of your body weight (*eg* if you weigh 150 pounds, each dumbbell should be 15 pounds). Individuals with less strength training experience may start with dumbbells which weigh 5% of body weight, while stronger athletes can use dumbbells checking in at 20% of body weight. You may need to experiment a bit, using a weight that makes the exercise challenging but achievable. If dumbbells are unavailable, a barbell of comparable total weight can be utilised. To do the exercise, stand upright with your feet spaced about hip to shoulder-width apart and your hands supporting the dumbbells in front of your shoulders. Squat down until your thighs form an angle of 90° with your shins (a half squat), while maintaining a reasonably upright posture with your torso and while keeping your hands in front of your shoulders. Then rise quickly from the squat position while pressing (pushing) the dumbbells overhead simultaneously. Both arms and legs should reach full extension at the same time (You will end up standing tall with legs straight and arms straight overhead). Then lower the dumbbells in a controlled fashion to the starting position. Repeat this three count movement smoothly and continuously.

How can this help you as an athlete?

Squats to presses increase strength and power in your legs, hips, low back, abdominals, shoulders, and arms. The whole body involvement of the squat to press increases your cardio respiratory requirements, compared to the more commonly used, isolated pressing exercises, such as bench and shoulder presses.

Body weight rows

For this one, you will need a horizontal bar or beam which is sturdy enough to support your body weight. Set the bar at approximately the height of your navel (when you are standing straight up). To start the exercise, grip the bar with both hands at slightly wider than shoulder-width, and hold your body in support underneath the bar. Your heels should be on the floor, and your body should be straight and rigid from your shoulders to your ankles. Then, with your feet acting as a fulcrum, pull your chest up to the bar by bending your elbows and pulling them backwards. Return to the starting position by straightening your arms in a controlled manner, and repeat the overall action for the time period specified in the chart.

How can this exercise help you?

The body weight row does for the back side of the body what the push-up does for the front side. Body weight rows improve pulling strength of the upper back, shoulder, and arm muscles, but they also serve to increase stabilising strength in the low back, gluteals, and hamstrings, all of which are critically important for quick movement whenever you participate in your sport. You will achieve a balance between lower and upper body strength by performing this exercise.

One leg squats

You will need a bench or step 6 to 8 inches in height. Stand with your left foot flat on the floor and your right foot behind you and elevated on the step. The distance between your feet should be approximately the length of your shin, and most of your weight should rest on the heel of your left foot. To do the exercise, bend your left knee and lower your body until the left knee makes an angle of 90º between the thigh and lower leg. Return to the starting position by straightening your left leg, while maintaining an upright posture with your trunk. Repeat this action with the left leg for the specified amount of time, and then switch to the right leg.

How do one leg squats help you?

This exercise develops muscle strength in the quads, hamstrings, and gluteals, the muscles which provide much of your power while running. The actual motion of the one leg squat closely resembles the 'front side' mechanics of the hip and knee during the actual running stride. By strengthening your hip and knee joints in a coordinated and integrated fashion, your leg strength and running power should improve tremendously. One leg squats can also help you improve your vertical jumping ability.

Low back stabilisers

For this exercise, you will need a bench, padded table, or 'Roman Chair' bench. Lie face down with your body extended and your hips at the edge of the supporting surface of the bench. Your arms should be extended straight down toward the floor in front of you. For added stability, it helps if your feet are wedged between the end of the bench and a wall. Smoothly raise both arms over your head simultaneously while maintaining your trunk in full extension (your body should be horizontal to the floor and held straight as an arrow), and then return both arms to the starting position. Repeat this action over and over again for the prescribed time period.

How can this exercise possibly benefit you?

Heightened low back strength provides for proper posture while running and also provides excellent 'motion control' of the torso and hips throughout the running stride. As a result, you will move more quickly, whether it is to return a serve on the tennis court or to reach the football in time to score a goal.

Remember that improvements in how your body functions can occur whenever you overload your body's systems. This circuit program provides an overload of your cardio respiratory system (especially the hard circuits), taxes your muscular system by forcing it to work against increased resistance, and forces the key joints involved in moving your body to go through a wider range of motion than they commonly encounter. The result, I believe, will be better, more powerful performances.

Walt Reynolds

Critical Swim Speed test

The Critical Swim Speed (CSS) test, devised by Ginne [1] in 1993, can be used to monitor the athlete's aerobic capacity. The result of the test can also be used to determine the appropriate target time for each repetition of a swimmer's aerobic training session. CSS is defined as "the maximum swimming speed that can theoretically be maintained continuously without exhaustion" [2] – just below the swimmer's lactate threshold.

Required resources

To undertake the CSS test you will require:

- Swimming pool
- Stop watch
- Assistant.

Test process

The following protocol should be followed:

- Start each swim from a push start – not a dive in
- Allow a full recovery between each swim
- Record the time for each swim in seconds
- Calculate the athlete's CSS.

How to conduct the test

The test comprises two maximal swims over 400 metres and 50 metres. A suitable rest period should be taken between each swim to allow the athlete to fully recover. The assistant should record the times for each swim.

Calculation of CSS

The calculation of the swimmer's CSS, based on their 400m and 50m times, is as follows:

CSS = (D2 – D1) / (T2 – T1)

Where D1 = 50, D2 = 400, T1 = time for 50m in seconds and T2 = time for 400m in seconds

Example:

A swimmer completes a 50m swim in 31 seconds and a 400m swim in 291 seconds:
CSS = (400-50) / (291-31)
CSS = 350 / 260
CSS = 1.35 metres/second

Use of CSS to set training times

The calculated CSS can be used to determine training times for an aerobic training session [1].

Example:

Training session is 6 x 400m. The time per 400m repetition can be calculated as follows:

Time per 400m repetition = Distance / CSS

For an athlete with a CSS of 1.35 then the 400m repetition time would be:
400 / 1.35 = 296.3 seconds = 4 minutes 56.3 seconds

Reliability

Reliability would depend upon how strict the test is conducted and the individual's level of motivation to perform the test.

References

1. Ginne, E. (1993), 'The application of the critical power test to swimming and swim training programmes'
2. Wakayoshi, K. et al (1991) 'Determination and validity of critical velocity as an index of swimming performance in the competitive swimmer,' *European Journal of Applied Physiology,* 64, 153-157

Brian Mackenzie

Module 7

Cardiovascular Endurance

Cardiovascular Endurance

The cardiovascular system comprises of the heart, blood, blood vessels and lymphatic system. The effects of regular exercise on this cardiovascular system are:

- The supply of blood to the heart will increase, thereby lowering blood pressure and improving the functioning of the heart
- Lowers the cholesterol levels in the blood helping to reduce the risk of arteries 'furring up' and possible heart disease
- The period needed for the heart rate to return to normal after exercise is reduced
- The network of capillaries in a muscle will increase, thereby increasing the supply of blood, oxygen and nutrients to the working muscle.

An individual's cardiovascular endurance can be measured by the volume of oxygen they can consume while exercising at their maximum capacity. VO_2max is the maximum amount of oxygen in millilitres one can use in one minute per kilogram of body weight. Those who are fitter have higher VO_2max values and can exercise more intensely than those who are not as well conditioned. Numerous studies show that you can increase your VO_2max by working out at an intensity that raises your heart rate to between 65 and 85% of its maximum for at least 20 minutes three to five times a week.

Overview of the articles in this section

- Ken McAlpine in his article 'Any change of pace is good for your running' explains how playing with running pace can provide endless variety, and these fartlek alternatives can lead to quick improvement

● Brian Mackenzie explains how to improve your stride length and frequency and how to breath effectively for running in his article 'How to improve your running economy'
● Raphael Brandon in his article 'What are the energy demands in maximal intermittent exercise sports?' explains the various energy systems and how energy is supplied for intermittent high intensity action sports like football.
● Brian Mackenzie explains how you can predict your VO_2max in his article 'Balke Test'.

The articles in this section are applicable to most sports.

Any change of pace is good for your running

The train is leaving in ten minutes, and Tom Warren is a mile from the station. These circumstances would present little problem if Warren were not on foot and running. Warren's dilemma is slightly more complicated than man chasing train.

Warren, you see, has been chasing this train for the past 4 hours. A 35 mile run up the Southern California coast from Pacific Beach to Oceanside where he hopes to hop on the train for a ride home. He has left the narrowest of windows, precisely timing his run from his home so he will have to push to make his connection. More of a stimulus, he explains. The window has proved narrower and more stimulating than Warren expected.

Forty-five years old and washboard hard, Tom Warren is anything but typical. Winner of the 1979 Hawaii Ironman Triathlon, he is a sweat boy with limitless stamina and imagination. The 35 mile train chase workout is a favourite. "For some reason," says Warren, "the run makes the train ride home really enjoyable."

Warren's excesses are not important nor does it matter to anyone, but Warren, whether he makes the train (he does). What does matter is the underlying premise behind his antics. Keep running interesting, keep it challenging, make it fresh and have fun.

Running author and 1972 Olympian Jeff Galloway tells you what you may already know. "A lot of people are into this tiresome routine of going out of the door and squeezing the same run on the same course into their schedule,"' says Galloway, who has heard hundreds of similar routines.

Setting off on a run does not have to be a personal Armageddon. Let us face it, running can be boring business. Unfortunately, many of us only aggravate the problem. The more variety and interest you add to your training program, the more improvement you can expect to gain from it.

The best runners know this and offer insights that can help you turn training drudgery into fresh and lively runs.

Hang loose

If you are looking for a bit more spice, start by being more flexible within your training schedule. If you have two hard runs and two easy runs planned for the week, stick to that plan, but play with it. You do not have to do the hard run on Wednesday just because the schedule calls for one, especially if you had a tough day at the office.

"The reality is that you are going to have days when you feel good and days when you feel bad, and you are not always going to be able to plan for that," says Pete Pfitzinger, who has ridden this hang loose work ethic to two Olympic Marathons. "Sure, you can force yourself through a hard run, but it will not be a good workout and it will not be a good experience."

Olympic Marathon gold medallist Frank Shorter also lays out a general schedule and then enjoys winging it "Until I wake up in the morning, I am not sure exactly what I am going to run," says Shorter, who credits this casual planning with keeping him fresh for 26 years of running. "I feel it is always a good idea to maintain a certain amount of mystery about your workouts. You have to mentally structure your workouts so that they do not become burdensome or boring."

Take it easy

It is also important to realise that even the most serious training programs have plenty of room for variety and fun. Shorter, self coached for years, believes that any runner, elite or jogger, needs no more than three hard workouts a week to achieve top condition. "That is the most I have ever been able to do, and that gets me as fit as I can get," he says. "All of your other running has a different kind of cardiovascular purpose. How it is accomplished is not that important"

Shorter is not alone in this belief. Ever since former University of Oregon coach Bill Bowerman introduced the hard easy concept in the early 1950s runners the world over have been reaping its benefits. Unfortunately, many recreational runners still feel that easy days are wasted, a psychological block most elite runners dispensed with years ago. "The average runner has a tendency to go hard every day, but if you run hard all the time you will go flat," Bowerman says. "Find workouts that you like, introduce a little variety and smell the flowers. Train hard on certain days, but when you are supposed to run easy, run easy. Not only will the easy days be more pleasurable, they will be more beneficial to your training. It is better to be a little under trained than over trained."

Shift gears

Another way to liven up your running is by varying the pace during some of your workouts. Top veteran Barry Brown has been competing for 32 years, long enough to run his way through four Olympic Trials, an American veterans marathon record (2:15:15) and more than his share of days when, as he puts it, “I am just putting one foot in front of the other.” Brown shakes off lethargy by tossing 20 second accelerations into his run. He surges and then settles back into a steadier pace for several minutes before accelerating again. Not only will 5 or 6 of these bursts snap you back to life, Brown says, they can also ‘trick’ you into a better workout.

“By the time you get back into a comfortable pace, it is much faster than you were going, and you are farther along in your run than you realised,” says Brown, who often varies the length of his pickups (20 seconds, 80 seconds and 40 seconds) throughout his run.

Brown also suggests that switching pace and changing gait in training runs can come in handy during races. “I have learned to react to changes in pace very quickly” says Brown, who on more than one occasion has shifted into high gear and stayed in the thick of the race.

Playing with pace can provide endless variety, and these fartlek alternatives can lead to quick improvement. Vince O’Boyle, the head track and cross country coach of the University of California at Irvine, has his runners do a wide variety of fartlek sessions, from one minute bursts with 30 second recoveries to eight minutes of sustained running interspersed with four minutes of recovery. While the variations are limitless, the rest periods are never long enough for a full recovery.

For those with a cramped schedule, fartlek offers a high quality, time efficient workout. “You warm up, throw in some fartlek work, and in 35 minutes you have got a better workout than just going out and running for the same amount of time,” says O’Boyle, who recommends such pace work once or twice a week.

Go new distances

The problem with the daily five mile slog is that it can dig you into a hole. Fight off the feeling that you have to run a certain distance each day or something catastrophic will happen. If you kick off your conversations with “I got my five miles in today,” it may be time to do yourself (and your friends) a favour. Lop off a couple of miles from your five miler, but run it faster.

“Shorten up the normal distance and increase the speed,” advises Pfitzinger, who has put this short but sweet premise to work on plenty of occasions. “When you run faster, you feel good, and that will get you revitalised.”

Or you can go for a long run and forget about distance entirely. Top road racer Keith Brantly occasionally saunters off on two hour runs and does not give a hoot about distance. “Just run,” Brantly says. “If you feel you have to, estimate how far you have run and go with that.”

Galloway is also a firm believer in the benefits of the long, slow run. Long runs, he says, offer several benefits, from fat burning to psychological head cleaning. Running farther can also breathe fresh air into a suffocating program. “You get this great sense of accomplishment on long runs of pushing back the barriers,” says Galloway, who recommends scheduling long, slow runs once every couple of weeks.

Long runs can open up into a wide range of alternatives. Bob Larsen, who now heads UCLA’s track and cross country programs, got his start in coaching at a high school near San Diego. On distance days, Larsen would gather his runners on a coastal road, send them north, wait a couple of hours, then hop in the car and pluck them up one by one. Chased by the spectre of Larsen, the faster runners would log distances they never thought possible.

“They wanted to get as far away from me as they could,” laughs Larsen. The kids loved these one way runs, because for some reason, they seemed to be more motivated going in one direction without having to loop back over the same roads.

“If you intersperse these longer types of runs once every week or two,” Larsen says, “when you come back to your regular run it seems easy.”

Kick off your shoes

One of the obvious beauties of running is it can be done virtually anywhere, a fact that escapes many of us who run exclusively on the road. Bruce Bickford, an Olympic 10,000m finalist, has had some of his best races after training primarily on grass. Rather than go to the track and reel off a set of 400s, Bickford will run 70 second ‘efforts’ on a golf course. Depending on the type of day he is having, this may or may not equate to 400m, but that is part of the allure. “If I am having a bad day, I do not really know how far I am running, so I do not worry about it,” Bickford says. “The point is to go out and run.”

Running on the grass is not just easier on the mind it also offers a different physical challenge. “Grass is softer, so it makes you work a little bit harder,” Bickford says. “I have friends who hate running on the grass just for that reason.”

One of the reasons Bickford does a lot of his training on golf courses is because his home in suburban Boston is near six of them, but just about any park or playing field will do. Even if you choose to run mainly on the roads, UCLA’s Larsen suggests finishing an occasional run with a bare foot jog on a soft, smooth grass surface. “Running barefoot,” Larsen says, “is a good way to cool down, and it stimulates the nerves in the bottom of your feet and increases circulation.”

Soft sand is even better than grass for barefoot running. Bear in mind that running barefoot on grass or sand drops your heel lower than normal putting a bit more strain on the Achilles tendons. Like any new form of running start slowly and allow your body time to adapt.

Hit the trails

Trail running offers yet another off road alternative. “No traffic, no frustration,” says 2:32 marathoner Maureen Roben who runs at least twice a week on the trails near her home in Denver. “One reason I have been relatively free of injuries,” she says, “is because of all the running I do on soft surfaces. Aside from that, I enjoy the running more than if I were pounding the roads every day.”

Australian marathon great Rob de Castella is another strong advocate of trail running. He does the bulk of his training on the paths through the Stromlo Forest, a short jog from his home in Canberra.

“Running in the forest is very relaxing,” Rob says. “It is so beautiful, I do not have to deal with noise and traffic, and I can run with friends. I want to enjoy my runs, not fight with cars.”

Larsen sometimes takes off on ‘exploring runs’ with his 11 year old son through the canyons behind their home in West Los Angeles. Trails disappear and rocks force them to stop and climb, none of which matters. “The whole idea,” Larsen says, “is to have fun, look around and get a bit of exercise.”

Exploring does not even have to be done in the wilds. On an occasional early Sunday morning, Larsen will run smack dab down some of the busiest streets in Los Angeles. “If I run early enough, I can go right down a major boulevard with virtually no traffic.”

Expand your horizons

When the snow piles up around triathlete Scott Molina’s home in Boulder, Colorado, he might strap on snowshoes. Winner of the 1988 Hawaii Ironman, Molina does not see this as peculiar at all. “Running on snowshoes opens up a bunch of options for me,” Molina says. “With snowshoes, I can run mountain trails, through forests or on the roads. Basically, I like snowshoes because they are a gas. It is also a great workout because it feels like I am running in combat boots.”

Innovation does not have to include running at all. Twice a week during certain times of the year, four times Olympian Francie Larrieu Smith plays her way through a circuit of intense calisthenics (hopping, skipping, jumping, push-ups, chin ups) that can reduce her to rubble.

"I feel like I have been in the weight room when I finish," says Larrieu Smith, who is approached by other runners wondering if all that fun can be good for you. "It is hard work, but I feel like I am playing when I do the circuit."

Road and track star John Gregorek, a firm believer in variety, mixes the two by running easy to a nearby field, bouncing through calisthenics and then running home. Plenty of room for fun and improvisation. "Think of all your old PE calisthenics and then throw out the ones that were really crazy," Gregorek advises. "Do the rest of them, and if you do them right, it can be very tough."

Beat it to...

Often considered, but often ignored, is the track. For many recreational runners, the track can be very threatening, which is a shame, considering the fun and benefits that can be had there. According to Frank Shorter, part of the reluctance springs from the mistaken belief that intervals have to be pounded out in large bunches.

Shorter points out that many world class distance runners, including Rob de Castella, do no more than three miles of speed work in one session, and recreational runners can reap benefits from even less.

"You should not be afraid to go and run three half miles on the track with a short recovery. That is not too much to scare anyone away," Shorter says. "Do them consistently, but keep the volume down and the recoveries short, and that should be enough to increase your speed."

Nor do you need be a slave to the clock. Pick a series of distances and vary the pace within each repetition. Say you choose to do four 400s. On the fast one, run the first 300 easy and accelerate the last 100. Then run the first 200 easy and accelerate the last 200. Continue bumping up the accelerations until you are accelerating through the entire 400. The beauty here is that you ignore the clock and concentrate instead on varying your effort.

"It removes the onus of the watch, but it also gives you quality speed work," says Barry Brown, who once spent three months banging out similar accelerations on a grass field, then returned to the track and took 16 seconds off his three mile best.

Battle the blues

Inevitably, there will be days when no amount of spice will help. If you are determined to stick it out, Brown recommends backing off your normal pace and concentrating on form. "When you are tired, you get sloppy and that just exacerbates the problem," Brown says. "You are fighting yourself."

There is, of course, no small irony in all this. Most of us run for fun. But running is not always fun and games. It takes plenty of effort and often challenges us, not always a pleasant prospect. Ever since we were old enough to have to undertake household chores, we learned a basic tenet of human nature: we do not want to do what we do not enjoy and, the fact is, sometimes we do not enjoy running.

In the wavering battle to get out of the door, variety can tip the scales in our favour. Tom Warren understands this. Warren does not chase trains to satisfy some deep seated commuting urge. Nor does the need to keep an appointment take the sting out of his 35 mile run. Train and chase are simply Warren's quirky ploy. Choose your own Windmill.

Ken McAlpine

How to improve your running economy

In many sports speed is an important attribute and ways to improve speed are sought after. In a simplistic view, to improve speed you need to increase stride length and/or stride rate. Many athletes and coaches initially concentrate on improving stride length only to find that both stride rate and speed decrease. It is perhaps more effective to work on stride rate because this increases the power in the leg muscles which in turn naturally increase stride length.

In a number of sports (*eg* football, basketball, netball, hockey) the athlete is required to conduct short bursts of effort and is then able to recover by getting oxygen back into the system. There are sports (*eg* running) where there is a long sustained burst of effort and oxygen consumption (breathing rhythm) needs to be effective and efficient. Running economy can also be enhanced by improving your vVO_2max.

Stride length and rate

Exercise physiologist Jack Daniels, PhD monitored the stride rate and stride lengths of the athletes in the 1984 Olympic track and field competitions. It was found that competitors in the shorter distances had longer stride lengths. Female stride lengths varied form 4 feet 10 inches (1 metre 47 cm) in the marathon to 6 feet 8 inches (2 metres 3 cm) for the 800 metres. Male stride length was 6 feet 2 inches (1 metre 88 cm) during the 10 kilometre race to just over 7 feet 9 inches (2 metres 36 cm) in the 800 metres.

In contrast, the stride rate did not vary significantly. Stride rates for all events, for both men and women, fell between 185 and 200 steps per minute.

Stride length – 100m sprinter

Work conducted by Hoffman on male 100 metre sprinters (10.4 to 11.0 seconds) indicated that the average stride length was 1.14 times the athlete's height. Similar work conducted by Rompotti on the best twelve 100m sprinters (11.0 to 12.4 seconds) at Stanford University concluded that the normal stride length was 1.17 times the athlete's height. Despite the differences in abilities of the athletes in each group the results are fairly similar.

Further work conducted by Atwater on twenty three 100m sprinters (9.9 to 10.4 seconds) concluded that the average stride length was 1.35 times the athlete's height. The possible reason for the differences in the results is that the work by Hoffman and Rompotti was conducted on cinder tracks; where as the work by Atwater was conducted on synthetic surfaces. Using Atwater's results the six foot athlete (1.8 metres) has an average stride length of 2.5 metres.

How to improve stride rate

The easiest way to determine your athlete's stride rate is to count the number of times their right foot lands during one minute of running. Repeat the one minute runs at different speeds from an easy jog to interval speed. If they are like an elite athlete you will find that their stride rate is 90 or more per minute (180 steps) and is similar for various speeds. If their stride rate is less than 90 then get them to make a conscious effort to increase the stride rate. To do this, concentrate on quicker, lighter, relaxed steps, but do not change the way their feet strike the ground. I have found that Aqua running often helps athletes with a slow strike rate.

Cross country runners need to maintain stride rate when running up hills by adjusting the stride length. If you let stride rate slow down you will find that fatigue sets in and it is harder to get back to the desired stride rate once they are over the crest of the hill.

Exercises to improve stride length and frequency

Perform the following three exercises in the order in which they are presented.

The high bench step-up: develops the hamstrings, with complimentary development of the gluteals (the 'buttock' muscles) and the quadriceps.

- Begin from a standing position on top of a high bench (approximately knee height), with your body weight on your left foot and your weight shifted toward the left heel
- The right foot should be free and held slightly behind the body
- Lower the body in a controlled manner until the toes of the right foot touch the ground, but maintain all of your weight on the left foot
- Return to the starting position by driving downward with the left heel and straightening the left leg

- Repeat for the prescribed number of repetitions, and then switch over to the right leg
- Maintain absolutely upright posture with the trunk throughout the entire movement, with your hands held at your sides (with or without dumbbells)
- Frequency: 2 to 3 times a week, 2 to 3 sets of 15 to 20 repetitions with 2 to 3 minutes recovery.

One leg squat: develops the quadriceps and gluteals, with a complimentary boost to the hamstrings.

- Stand with the left foot forward and the right foot back, with the feet about one shin length apart (your feet should be hip width apart from side to side)
- Place the toes of the right foot on a block or step which is 6 to 8 inches high. As in the step up exercise, most of the weight should be directed through the heel of the left foot
- Bend the left leg and lower the body until the left knee reaches an angle of 90° between the thigh and lower leg
- Return to the starting position, maintaining upright posture with the trunk and holding your hands at your sides
- Complete the prescribed number of repetitions with the left leg before switching to the right leg
- Frequency: 2 to 3 times a week, 2 to 3 sets of 15 to 20 repetitions with 2 to 3 minutes recovery.

One leg hops in place: builds strength and co-ordination in the entire lower extremity, including the foot, ankle, shin, calf, thigh, and hip.

- Start from the same position you used for the one leg squat, with the toes of the right foot supported by a 6 to 8 inch block
- Hop rapidly on the left foot at a cadence of 2.5 to 3 hops per second (25 to 30 foot contacts per 10 seconds) for the prescribed time period
- The left knee should rise about 4 to 6 inches, while the right leg and foot should remain stationary
- The left foot should strike the ground in the area of the mid foot and spring upwards rapidly as though it were contacting a very hot plate on a cooker
- The hips should remain level and virtually motionless throughout the exercise, with very little vertical displacement.
- After hopping for the indicated time on the left leg, switch to the right leg and repeat the exercise
- Frequency: 2 to 3 times a week, 1 to 2 sets of 10 to 20 seconds with 2 to 3 minutes recovery.

The breathing issue

Most elite athletes use a 2-2 breathing rhythm. That is they breathe in for two steps and they breathe out for two steps. The 2-2 breathing rhythm means you are taking 45 breaths (assume you now have a stride rate of 90) which is slow enough to allow for good depth of breathing. It is recommended to practice all kinds of breathing patterns, just to become familiar with them and to note your body's reaction. Try the 3-3 breathing rhythm, 4-4 breathing rhythm and also try unequal breathing rhythms such as 3-2 and 2-3. All the athletes I work with (except the sprinters) use either a 2-2 or 3-3 breathing rhythm. I personally use the 2-2 breathing rhythm starting the breathing cycle on the left foot. If you use the 2-2 breathing rhythm and you experience stitch then switch the breathing rhythm to start on the other foot or switch to a 3-3 breathing rhythm until the stitch subsides.

Long term analysis conducted by Jack Daniels has found that elite athletes in races up to and including the 10K use the 2-2 breathing rhythm at the start of the race and after completing about two thirds of the race they switch to a 2-1 breathing rhythm. For races longer than 10k the 2-2 breathing rhythm is used for the whole distance, perhaps shifting to a 2-1 breathing rhythm in the last minute or two for the sprint finish. An important point is that your breathing rhythm will not only tell you how hard you are working but also allow you to control how hard you work.

Brian Mackenzie

What are the energy demands in 'maximal intermittent exercise' sports?

Just to remind you, there are three major systems available for the production of energy in the muscles: the ATP-PC system for high-intensity short bursts; the anaerobic glycolysis system for intermediate bursts of relatively high intensity (this system produces the by products of lactate ions and hydrogen ions, commonly known as lactic acid) and finally, there is the aerobic system for long efforts of low to moderate intensity.

With sporting events such as cycling, swimming and running, where the intensity is constant for the duration of the event, it is possible to estimate the relative contribution of each energy system. For example, the energy for the 100 metre sprint is split 50% from the ATP-PC system and 50% from the anaerobic glycolysis system, whereas the marathon relies entirely on the aerobic system (Newsholme et al, 1992) [(4)]. By contrast, games such as football are characterised by variations in intensity. Short sprints are interspersed with periods of jogging, walking, moderate-paced running and standing still. This kind of activity has been termed 'maximal intermittent exercise'.

It would seem reasonable to assume that during a football game all three energy systems would be required, as intensity varies from low to very high. However, because it is not obvious just how fast, how many and how long the sprints are, and just how easy and how long the intervening periods are, it is difficult to determine which of the energy systems are most important. Thus most of the football-related research has attempted to tackle this problem.

A 15m sprint every 90 seconds

English researchers Reilly and Thomas (1976) [7] investigated the patterns of football play in the old first division. They found that a player would change activity every 5 to 6 seconds, and on average he would sprint for 15 metres every 90 seconds. They found the total distance covered varied from 8 to 11km for an outfield player – 25% of the distance was covered walking, 37% jogging, 20% running below top speed, 11% sprinting and 7% running backwards. Ohashi and colleagues [5], researching football in Japan, confirmed these findings, showing 70% of the distance was covered at low to moderate pace below 4m/s, with the remaining 30% covered by running or sprinting at above 4m/s. Thus, for example, if a football player covers 10km in total, around 3km will be done at fast pace, of which probably around 1km will be done at top speed.

The pattern of football play has also been expressed in terms of time. Hungarian researcher Peter Apor [1] and the Japanese researchers [5] both describe football as comprising sprints of 3 to 5 seconds interspersed with rest periods of jogging and walking of 30 to 90 seconds. Therefore, the high to low intensity activity ratio is between 1:10 to 1:20 with respect to time. The aerobic system will be contributing most when the players' activity is low to moderate, *ie* when they are walking, jogging and running below maximum. Conversely, the ATP-PC and anaerobic glycolysis systems will contribute during high-intensity periods. These two systems can create energy at a high rate and so are used when intensity is high.

The above research has described the average patterns of play during football and from this we can reasonably deduce when each of the energy systems is contributing most. However, now we need to establish just how important each energy system is for success.

Recovering from high-intensity bursts

There is evidence that the aerobic system is extremely important for football. Along with the fact that players can cover over 10km in a match, Reilly [3] found heart rate to average 157 bpm. This is the equivalent of operating at 75% of your VO_2max for 90 minutes, showing that aerobic contributions are significant. This is confirmed by the fact that various studies have shown footballers to have VO_2max scores of 55 to 65 ml/kg/min. These VO_2max scores represent moderately high aerobic power. Reilly and Thomas (1976) [7] showed that there was a high correlation between a player's VO_2max and the distance covered in a game. This was supported by Smaros (1980) [8] who also showed that VO_2max correlated highly with the number of sprints attempted in a game. These two findings show that a high level of aerobic fitness is very beneficial to a footballer.

The greater the player's aerobic power the quicker he can recover from the high-intensity bursts. These short bursts will be fuelled by the ATP-PC and anaerobic glycolysis systems. Then, during rest periods, a large blood flow is required to replace the used-up phosphate and oxygen stores in the muscles and to help remove any lactate and hydrogen ion by-products. The quicker this is achieved, the sooner a player can repeat the high-intensity sprints, and thus cover more distance and be able to attempt more sprints. So the aerobic system is crucial for fuelling the low to moderate activities during the game, and as a means of recovery between high-intensity bursts.

Which system fuels the sprints?

As already mentioned the ATP-PC and anaerobic glycolysis systems fuel the high-intensity periods. However, if we are to optimise training programs, we need to know whether in performing the high-intensity bursts both systems contribute evenly or whether one is more important.

As the sprints a player makes are mostly 10 to 25 metres in length, or 3 to 5 seconds in duration, some researchers have assumed that the ATP-PC system will be the most important. However, since football has an intermittent intensity pattern, just because the sprints are brief does not mean that anaerobic glycolysis does not occur; research has shown that anaerobic glycolysis will begin within 3 seconds.

To determine whether anaerobic glycolysis is significant during football, researchers have analysed blood lactates during match play. However, results from these studies have varied. Tumilty and colleagues [9] from Australia cite research varying from 2 mmol/l, which is a low lactate score indicating little anaerobic glycolysis, to 12 mmol/I, which is quite a high score. Most studies seem to find values in the 4-8 mmol/I range, which suggests that anaerobic glycolysis has a role.

The contrast in results is probably due to the varying levels of football in the different studies. Some use college-level players, others professionals. Some studies test training games, others competitive matches. This is likely to confound results. Ekblom [2], a researcher from Sweden, clearly showed that the level of play was crucial to the lactate levels found. Division One players showed lactate levels of 8-10 mmol/1 progressively down to Division Four players showing only 4 mmol/1. Tumilty and colleagues [9] conclude that the contribution of anaerobic glycolysis remains unclear, but is probably significant. They suggest that the tempo of the game may be crucial to whether anaerobic glycolysis is significant or not. As Ekblom noted: "It seems that the main difference between players of different quality is not the distance covered during the game but the percentage of overall fast-speed distance during the game and the absolute values of maximal speed play during the game".

The conclusion from these lactate studies is that, as the playing standard increases, so may the contribution of anaerobic glycolysis. However, I think more precise research is needed to determine exactly how fast and how frequent the high-intensity efforts during play are. Maximum-intensity bursts with long recoveries will emphasis the ATP-PC system, whereas high-intensity but not maximal bursts occurring more frequently will emphasise the anaerobic glycolysis system more. Thus, along with the standard, the style of play and football culture may also influence the physiological demands. This means that the country in which the researchers are based may affect the conclusions they draw when studying the relative contributions of the two systems.

What action to take

From the research completed so far, it would probably be fair to conclude that for the high-intensity bursts during play both the anaerobic glycolysis and the ATP-PC systems contribute, but that the ATP-PC system is more important. This is because the ratio of high-intensity to low-intensity activity is between 1:10 and 1:20 by time. The high-intensity periods are very short and the rest periods relatively long. Therefore, the ATP-PC system will probably be more useful and also has sufficient time to recover. Research has also shown that lactate values become moderately high but not so high as to indicate that the anaerobic glycolysis system is working extremely hard. Indirectly, this is confirmed by Smaros [8] who showed that glycogen depletion was mostly in the slow-twitch muscle fibres, which suggests that glycogen is being used for the aerobic system but not the anaerobic system. However, the possibility exists that for professional-standard football, or football played at a high tempo, anaerobic glycolysis will be at least as significant as ATP-PC.

If coaches of professional teams want to know better which system is more important, then more research taking place in their own country and using top players as subjects is needed, accurately analysing intensity patterns in match play and measuring lactate levels. Until then, training regimes must cater for all three systems, with particular attention to the aerobic and ATP-PC systems. Japanese researchers [6] performed a Maximal Intermittent Exercise (MIE) test on footballers which consisted of 20 x 5 seconds maximum efforts with 30 seconds active rest. This was meant to mimic a high-intensity section of the game. They correlated the performance on this test with fitness tests representing the three energy systems, VO_2max for the aerobic system, lactic power for the anaerobic glycolysis system, and maximum power for the ATP-PC system. All three components of fitness were significant to the performance on the MIE test. Peter Apor [1] agrees with this in making fitness recommendations for footballers, saying that a good aerobic fitness needs to be linked to a moderate anaerobic glycolysis power and a high ATP-PC power.

A specific type of interval training for footballers would be to mimic the demands of an actual game with the correct work-to-rest ratios and distances covered. If players sprint for over 1 km during a game with high to low ratios of 3 to 5 seconds to 30 to 90 seconds, then a session such as two sets of 20 x 25m maximal sprints with 30 seconds rest (2 minutes between sets), would represent the demands of a tough match, namely, frequently repeatable high power. To focus solely on the ATP-PC system, short maximal sprints of 20 to 60 metres with 1 to 2 minutes recovery are best. To train the anaerobic glycolysis system, longer sprints of 15 to 30 seconds, with 45 to 90 seconds recovery, are recommended. Aerobic training involves running continuously, fartlek, long repetitions (*eg*, 6 x 800 metres, 1 minute rest) or extensive intervals at moderate speeds (*eg* 30 x 200 metres, 30 seconds rest). Trainers should be aware that running sessions, intervals and shuttle runs (or doggies) should be carefully planned so that they target the correct energy system. Running speeds, distances and rest periods should be calculated so that the session will target the specific energy system the coach wants to develop.

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Raphael Brandon

Balke test

The Balke test can be used to predict an athlete's VO_2max.

Requiredresources

To undertake this test you will require:

- 400m track
- Stop watch
- Assistant.

How to conduct the test

The Balke Test is conducted as follows:

- Choose a windless day and run around a track for 15 minutes – the aim is to run as far as possible
- The assistant notes the total distance achieved in the 15 minutes to the nearest 25 metres.

Analysis

Analysis of the result is by comparing it with the results of previous tests. It is expected that, with appropriate training between each test, the analysis would indicate an improvement. The distance achieved can also be used to predict the athlete's VO_2max.

Performance assessment

The formula used to calculate VO_2max (*Obsession for Running* by Frank Horwill) is:

$$VO_2max = (((\text{Total distance covered} / 15) - 133) \times 0.172) + 33.3$$

Example

- An athletes completes 5200 metres in 15 minutes
- $VO_2max = (((5200/15) - 133) \times 0.172) + 33.3$
- VO_2max = 70 mls/kg/min.

Target group

This test is suitable for endurance athletes and players of endurance sports (*eg* football, rugby) but not for individuals where the test would be contraindicated.

Reliability

Reliability would depend upon how strict the test is conducted and the individual's level of motivation to perform the test.

Validity

There are published VO_2max tables and the correlation to actual VO_2max is high.

Ideal VO_2max scores for various sports

VO_2max	Sport
>75 ml/kg/min	Endurance Runners and Cyclists
65 ml/kg/min	Squash
60-65 ml/kg/min	Football (male)
55 ml/kg/min	Rugby
50 ml/kg/min	Volleyball (female)
50 ml/kg/min	Baseball (male)

Brian Mackenzie

Module 8

Strength Endurance

Strength endurance

Strength endurance is the specific form of strength displayed in activities which require a relatively long duration of muscle tension with minimal decrease in efficiency. Sports that involve strength endurance are numerous in nature from the rower to the swimmer to the wrestler on the mat. Even these examples are differentiated by the abilities expressed, dynamic or static, general or local strength endurance.

All forms of competition, however, necessitate maximal output over the duration of the event. It is not always the strongest athlete who wins in all cases, rather the one that can sustain the most power over the full term of the activity. Therefore, development of all the various types of muscle fibres benefits the athlete.

Predominantly the fast twitch muscle fibres create maximum power output in the explosive sports such as sprinting and weightlifting. Slow twitch fibres are the prime fibre cells used in long distance aerobic events. Combining, and training, these two types of fibres at all speeds and angles produces strength endurance.

Overview of the articles in this section

- John Shepherd in his article 'All you need to know about developing fast twitch muscle fibre for speed, power and strength' explains the best training methods for fast twitch motor units
- John Shepherd explains how to increase your endurance capacity in his article 'Why endurance athletes cannot afford to ignore the vital contribution of fast-twitch muscle fibres'

- Brian Mackenzie in his article 'Continuous and interval training' explains the benefits of and how to conduct continuous and interval training
- Les Archer explains the secret of power training and provides examples of appropriate power exercises in his article 'Power gym training for athletes'
- Brian Mackenzie in his article 'Chins test' explains how you can test arm and shoulder muscular endurance.

The articles in this section are applicable to most sports.

All you need to know about developing fast twitch muscle fibre for speed, power and strength

Let us get out of the blocks straight away, with our fast-twitch fibres blazing; on the 'B' of the bang, as Colin Jackson once put it!

There are more than 250 million muscle fibres in our bodies and more than 430 muscles that we can control voluntarily. Fibres are, in fact, bundles of cells held together by collagen (connective tissue). Each fibre consists of a membrane, numerous nuclei and thousands of myofibrils (inner strands) that run the length of the fibre.

In order to perform a sport skill, numerous muscles and muscle fibres have to interact. The process is controlled by the brain, which sends out electrochemical messages to the muscles via the spinal cord. These signals are received in the muscles by 'anterior motoneurons', whose role is to stimulate muscular contraction. Muscular force is generated through the interaction of two protein filaments that constitute the myofibril: actin and myosin.

Anterior motoneurons and motor units can be likened to a car's starter motor, while the brain is like the key; the former kicks the muscle fibres into action (or rather 'contraction') after the latter has been turned.

Some muscles have large numbers of motor units and relatively few fibres, which enables them to execute highly precise movements. One such muscle is the eye, which has one motor unit for every 10 muscle fibres. By contrast, the gastrocnemius (calf muscle), which performs larger, more powerful movements, has 580 motor units to 1.3 million fibres.

The interaction that occurs at muscular (and tendon and joint) level is two-way, since there are built-in feedback and control mechanisms to prevent muscles from damaging themselves by over-contracting. Proprioceptive (feedback mechanism) components of motor units, joints and ligaments continually monitor muscular stretch and swing into action if, for example, a limb is moved beyond its normal range. This is achieved by muscle spindles 'pulling back' on muscle fibres to reduce the stretch. This 'stretch/reflex' is a vital component of our body's muscular safety mechanism, but it can also play a significant role in developing greater fast-twitch muscle power *(see Table 2)*.

Fast-twitch fibres, also known as 'white' or 'type II' fibres, contract two to three times faster than their slow-twitch counterparts, producing 30 to 70 twitches per second, compared with 10 to 30 for slow-twitch.

There are two basic types of fast-twitch fibre:

- Type IIa, aka 'intermediate' fast-twitch fibres or 'fast oxidative glycotic' (FOG) fibres because of their ability to display, when exposed to the relevant training stimuli, a relatively high capacity to contract under conditions of aerobic or anaerobic energy production
- Type IIb fibres, the 'turbo-chargers' in our muscles, which swing into action for a high-performance boost when needed. These are also known as 'fast glycogenolytic' (FG) fibres, since they rely almost exclusively on the short-term alactic/glycotic energy system to fire them up.

Slow-twitch fibres, aka type I, red or slow oxidative fibres, are designed to sustain slow but long-lived muscular contractions and are able to function for long periods on aerobic energy.

Most coaches and athletes will be familiar with type IIa and type IIb fast-twitch fibres, but it should be noted that other types have been identified. Former national athletics coach Frank Dick has described a further seven sub-divisions, although the differences between these are not considered significant enough for them have a crucial effect on sports conditioning [(1)].

Fast-twitch fibres are thicker than slow ones and it is the former that grow in size (hypertrophy) when activated by the 'right' training.

Activating fast-twitch motor units is the key to improved strength, speed and power. Unlike slow-twitch motor units, which are responsible for most of our day-to-day muscular activity, fast-twitch units are quite lazy and tend to slumber until called to action.

The role of mental energy

To recruit these units takes powerful movements, possibly fuelled by an excited hormonal response associated with increased adrenaline and neural stimulation (such as in throwing a very heavy object, like a desk, in frustration).

In terms of producing more power, this works because the increased mental energy boosts the flow of electrical impulses to the muscle, generating increased muscular tension.

It should be pointed out that extreme levels of this 'neuronal stimulation' can lead to impaired sports performance. For example, a golfer relies on the synchronous firing of fast-twitch motor units during the 'swing'; but if he/she becomes overly aggressive and 'tries too hard' a poor stroke usually results, even though his fast-twitch motor units could be capable of expressing more power because of their increased state of tension.

Fast-twitch muscle fibre is recruited synchronously – *ie* all at the same time – within its motor unit. This is, in part, a physiological manifestation of a neural activity – sports skill learning. Let us use sprinting to explain this. Carl Lewis had a wonderful silky sprint action. His finely-honed techniques allowed his fast-twitch motor units to fire synchronously and apply power. The end result was championship and world record-breaking form. In short, Lewis's neural mastery of sprinting form allowed his fast-twitch motor units to fire off smoothly, operating like cogs in a well-oiled machine. It also allowed him to recruit the largest, and therefore most efficient, power-producing units. This latter ability is a further key element in developing optimum fast-twitch motor unit power.

By contrast, slow-twitch muscle motor units are recruited asynchronously, with some resting and others firing when carrying out endurance activity.

Fast-twitch motor units are recruited according to the 'size principle', in that the more power, speed or strength an activity requires, the larger the units called in to supply the effort. It would, however, take a flat-out sprint or a near PB power clean to fully activate them. This means that power athletes have to be in the right frame of mind to get the most out of their fast-twitch motor units. There is no such thing as an easy flat-out sprinting session or power-lifting workout.

By contrast, the endurance runner could go for a 60-minute easy 'tick-over' effort and drift mentally away from the task while still giving his or her slow-twitch motor units a decent workout.

It is often assumed that those blessed with great speed or strength are born with a higher percentage of fast-twitch muscle fibres, and that no amount of speed work (or neuronal stimulation) will turn a cart-horse into a race horse. But, in fact, fast-twitch fibres are fairly evenly distributed between the muscles of sedentary people, with most possessing 45 to 55% of both fast- and slow-twitch varieties.

Thus few of us are inherently destined for any particular type of activity, and how we develop will depend mostly on two factors:

- The way our sporting experiences are shaped at a relatively early age
- How we train our muscle fibres throughout our sporting careers

Table 1 *(opposite)* compares fast-twitch muscle percentages in selected sports activities with those of sedentary individuals – and a very speedy animal. Note the extremes of muscle fibre distribution. The right training will positively develop more of the fibres needed for either dynamic or endurance activity, although the cheetah may not be aware of this!

Table 1: Fast twitch muscle % compared

Subject	Fast Twitch muscle fibre %
Sedentary	45 to 55%
Distance runner	25%
Middle distance runner	35%
Sprinter	84%
Cheetah	83%

Adapted from Dick page 109 [1] and Williams (97) [2]

Ross et al studied motor unit changes in sprinters and concluded that positive adaptations of muscle to sprint training could be divided into [4]

- Morphological adaptations, including changes in muscle fibre type and cross-sectional area – *ie* the ability of fast-twitch muscle fibres to exert more power by increasing in number and/or size
- Metabolic adaptations to energy systems to create more speed – *eg* a greater ability to complete short repeated maximal efforts, acquired through an improvement in the short-term alactic/glycotic energy system which is, in turn, gained from the creation and replenishment of high-energy phosphates.

Similar finding were made by Abernethy and his team, who compared sprint training methods with those used by endurance athletes. [4]

Table 2 summarises the best methods for enhancing fast-twitch motor units. Conversely, the wrong training – and even what might in some cases seem to be the ‘right’ training – can compromise their development.

Let us return to the sprint training research of Ross and his team. [3] They believed that volume and/or frequency of sprint training beyond what is optimal for an individual can induce a shift towards slower muscle contractile characteristics. Basically, this means that if a sprinter were to perform too many under speed track repetitions then his top speed would be impaired.

What is best for power athletes?

For 100% power athletes (such as 100m sprinters) and even those involved in sports where occasional maximal or near maximal quick flashes of power are required, such as golf, baseball (pitching and batting) and football (goal keeping), it may well be that high-intensity training sessions, interspersed with long periods of rest, are best for the optimum development of fast-twitch motor units, particularly in-season.

This can make the conditioning process very difficult. In the England cricket team, for example, batsmen are often encouraged to develop their aerobic fitness by running during down times in matches, and during pre-season. Although a general level of aerobic fitness is useful, it is possible that too much steady state work, particularly in-season, could blunt the batsmen's sharpness and dull their fast-twitch motor units.

In-season it may be far better for them to condition themselves using sprints, medicine ball work and autogenic training (a form of mental conditioning). Think of the cheetah in our muscle fibre distribution table. What does this fastest land animal do? It lies around all day, exploding into action every now and again: fast-twitch fibre development heaven – but hell for its prey!

In support of this point, Ross's team noted that detraining appeared to shift the contractile characteristics of fast-twitch motor units towards type IIb, thus providing them with more potential oomph. This effect can often be seen in power athletes who sustain minor injuries after a good period of training and are then obliged to train lightly for 2 to 3 weeks. Afterwards, to their complete surprise, they often produce a PB because the enforced rest has facilitated the fibre shift and upped their fast-twitch potential. Other research has indicated that a decrease in weight training after a prolonged period of training can have a similar effect. [5]

Note, though, that too long a lay-off can produce less positive effects, due to muscle shrinkage (atrophy) in sports where muscle size is also important, *eg* for shot putters and American football line-men.

Table 2: The best training methods for fast twitch motor units

Method	Comments
Lifting weights in excess of 60% 1RM	The heavier the weight, the greater the number and size of fast-twitch motor units recruited. A weight in excess of 75% 1RM is required to recruit the largest units
Performing a physical activity flat-out – *eg* sprinting, swimming, rowing or cycling as fast as possible	Good recoveries are needed to maximise effort. The short-term anaerobic energy system will positively adapt. The minimum speed needed to contribute towards absolute speed development is 75% of maximum
Training your muscles eccentrically	Research indicates that this form of training increases fast twitch motor unit recruitment. (6) An eccentric muscular contraction generates force when muscle fibres lengthen (see plyometric training, below)
Plyometric training	These exercises utilise the stretch-reflex mechanism, allowing for much greater-than-normal force to be generated by pre-stretching a muscle (the eccentric contraction) before it contracts. A hop, bound or depth jump is an example of a plyometric conditioning drill; a long jump take-off is an example of a plyometric sport skill.

Complex training	This can induce greater recruitment of fast-twitch motor units by lulling the protective mechanisms of a muscle into reduced activity, allowing it to generate greater force. Complex training involves combining weights exercises with plyometric ones in a systematic fashion. A good example is: 1 set of 10 squats at 75% 1RM followed, after a 2-minute recovery, by 10 jump squats, repeated 3 times
Over-speed training	This will have a transferable neural effect only if the athlete consciously moves his own limbs at the increased pace. It includes downhill sprinting and hitting or throwing sports using lighter implements
Good recovery	24-48 hours recovery should be taken between very intense plyometric/complex training and speed work sessions. A further 24-36 hours recovery will result in an over-compensatory peak – *ie* opportunity for a peak performance
Sport specific warm-up	This will reduce the risk of injury, increase the receptivity of the neuromuscular system to the ensuing work and reduce the potentially contradictory effects of non-specific preparation on fast-twitch motor units
Mental preparation	Maximum fast-twitch motor unit recruitment can result from specific mental preparation before and during competition

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John Shepherd

Why endurance athletes cannot afford to ignore the vital contribution of fast-twitch muscle fibres

In the last article, I offered the low down on maximising fast-twitch muscle fibre potential for speed and power. This article focuses on getting the most out of muscle fibre for endurance activity.

Biopsies are used to determine what types of fibres exist within our muscles. A special needle is pushed into the muscle and a grain-of-rice-size piece of tissue extracted and chemically analysed. Two basic fibre types have been identified via this process: slow-twitch (also known as type I or 'red' fibres) and fast-twitch (aka type II or 'white' fibres). Type II fibres, as we shall see, can be further sub-divided into type IIa and type IIb variants.

Slow-twitch muscle fibre contracts at almost half the speed of fast-twitch fibre – at 10 to 30 twitches per second compared with 30 to 70. Slow-twitch fibre has a good level of blood supply, which greatly assists its ability to generate aerobic energy by allowing plentiful supplies of oxygen to reach the working muscles and numerous mitochondria.

Mitochondria are cellular power plants; they function to turn food (primarily carbohydrates) into the energy required for muscular action, specifically adenosine triphosphate (ATP). ATP is found in all cells and is the body's universal energy donor. It is produced through aerobic and anaerobic energy metabolism and, consequently, through the associated actions of both slow and fast-twitch muscle fibre.

Slow-twitch fibre is much less likely than its fast-twitch counterpart to increase muscle size (hypertrophy), although well-trained endurance athletes have slow-twitch fibres that are slightly enlarged by comparison with sedentary people. The most notable training effects, however, occur below the surface.

Subject to relevant endurance training, these unseen changes include:

- An improved aerobic capacity caused by fibre adaptation. Specifically this involves an increase in the size of mitochondria, boosting the ability of the fibres to generate aerobic energy
- An increase in capillary density, which enhances the fibres' capacity to transport oxygen, and thus to create energy
- An increase in the number of enzymes relevant to the Krebs cycle – a chemical process within muscles that permits the regeneration of ATP under aerobic conditions. The enzymes involved in this process may actually increase by a factor of two to three after a sustained period of endurance training.

Blood lactate plays a crucial role in energy creation which is not, as many people mistakenly assume, restricted to the latter stages of intense exercise.

Lactate is actually involved in energy production in our muscles at all times, although response to lactate generation varies according to fibre type. A brief consideration of this process will begin to explain why the relationship between fast and slow-twitch fibre is crucial to optimum endurance.

Fast-twitch fibres produce the enzyme lactate dehydrogenase (LDH), which converts pyruvic acid (PA) into lactic acid (LA). The LDH in slow-twitch muscle fibre however, favours the conversion of LA to PA. This means that the LA produced by the fast-twitch muscle fibres can be oxidised by the slow-twitch fibres in the same muscle to produce continuous muscular contractions.

When LA production reaches a level where it cannot be recycled to generate steady-state aerobic energy, endurance exercise moves into anaerobic territory – with less reliance on oxygen and more on stored phosphates for energy production.

There will come a point, under these conditions, when an athlete reaches his or her 'lactate threshold', at which point further exercise becomes increasingly difficult and the athlete is forced to slow down and ultimately stop.

As we shall see later, this 'anaerobiosis' and its exercise-halting effect may be as much a consequence of brain activity as of muscular limitations, especially under extreme endurance conditions.

Well-trained endurance athletes are able to generate blood lactate levels that are 20 to 30% higher than those of untrained individuals under similar conditions. This makes for significantly enhanced endurance as their muscles no longer drown in lactate but rather 'drink' it to fuel further muscular energy. To continue the analogy, the untrained individual's muscles would get 'drunk' on lactate after just a few intervals – or should that be rounds!

As noted, failure to train fast-twitch fibre to contribute to endurance performance will result in lactate threshold being reached – and performance arrested – at a much earlier point. Unlike the 100m sprinter, who can ignore his slow-twitch fibres altogether in training without damaging performance, the endurance athlete has to train all fibre types in order to maximise sustained muscular energy.

Athletes are made rather than born

As I pointed out in my previous article, most people are born with a relatively even distribution of fast and slow-twitch fibres, suggesting that power and endurance athletes are 'made' rather than born. As exercise physiologists McKardle, Katch and Katch point out, 'studies with both humans and animals suggest a change in the biochemical-physiological properties of muscle fibres with a progressive transformation in fibre type with specific and chronic training'. (1)

Table 1 shows the extent to which fibre type can be 'altered' after training for selected endurance activities, although whether these changes are lasting is open to debate, as we shall see.

Table 1: Percentage slow-twitch fibre in male deltoid (shoulder) muscle

Endurance athlete	% slow-twitch fibre muscle in deltoid
Canoeist	71%
Swimmer	67%
Triathlete	60%

Adapted from McKardle et al' (5)

We have shown how slow-twitch fibre adapts to endurance training. Now let us take a look at how fast-twitch fibres respond.

- Type IIa or 'intermediate' fibres can, in elite endurance athletes, become as effective at producing aerobic energy as slow-twitch fibres found in non-trained subjects. Like slow-twitch fibres, these fibres (and their type IIb counterparts) will benefit from an increase in capillary density. In fact, it has been estimated that endurance training that recruits fast and slow-twitch muscle fibre can boost intramuscular blood flow by 50 to 200% (2)

- Type IIb fibres can play a much more significant role in sustained energy release than had been assumed, according to research carried out by Essen-Gustavsson and associates. (3) These researchers studied muscular enzyme changes brought about by endurance training and concluded that type IIb fibres were as important to endurance athletes in terms of their oxidative energy production and the clearance of exercise-inhibiting phosphates as type IIa fibres.

A raft of relatively recent research indicates that intense training efforts – *eg* 3-minute intervals at 90 to 95% of max heart rate/over 85% of VO_2max, with 3-minute recoveries – are great ways to boost lactate threshold (as well as VO_2max, economy and strength). These 'lactate-stacker' sessions, by their very nature, rely on fast-twitch fibre to generate power. Note, though, that these workouts are very tough and stressful and should be used judiciously.

Endurance gains can be made much more quickly through capillary adaptation in fast and slow-twitch fibre with anaerobic training methods, such as the lactate stacker workouts, than with less intense aerobic training.

Although it is possible to train fast-twitch fibre to take on more of the slow-twitch blueprint, taken to extremis – especially through the use of slow-twitch steady state training – this may not actually be the best strategy for endurance athletes.

The marathon runner Alberto Salazar once said that he aimed to train aerobically hard enough to lose his ability to jump. (4) In other words, he was trying to convert all his fast-twitch fibres into slow-twitch ones in terms of their energy-producing potential so that they could contribute all their energy to his marathon running.

However, for a variety of reasons, losing all fast-twitch speed and power ability may not actually be a good idea. For example, at the end of a closely-fought marathon there may be a need for a sprint, requiring fast-twitch fibre input.

Even more specifically, there is the anaerobic/aerobic component of an endurance activity to consider, and the speed required to complete it competitively. An 800m race or a 2k row calls for an anaerobic energy contribution of around 40%, and athletes in these disciplines must be fast and powerful to succeed.

Fast-twitch fibres have to be trained accordingly; it is no good turning them into plodders with an emphasis on slow-twitch, steady state work, if they are needed to produce a short or sustained kick and a sizeable energy contribution.
The recent research into lactate stacker sessions and the vital role of lactate

threshold as the key endurance performance variable further substantiates the need for the development of a high-powered endurance contribution from fast-twitch fibres.

Despite virtually undisputed evidence that all muscle fibre types will adapt to a relevant training stimulus, it is less certain whether these changes are permanent. One of the few studies concerned with the long-term effects of endurance training was conducted by Thayer et al, who looked at muscle-fibre adaptation over a decade [6]. Specifically, they compared skeletal muscle from the vastus lateralis (front thigh) in seven subjects who had participated in 10 years or more of high intensity aerobic training with that of six untrained controls.

They found that the trained group had 70.9% of slow-twitch fibres compared with just 37.7% in the controls. Conversely, the trained group had just 25.3% fast-twitch fibre, compared with 51.8% in the controls. The researchers concluded that endurance training may promote a transition from fast to slow-twitch fibres, and that this occurs at the expense of the fast-twitch fibre population.

Fibre reversion after inactivity

However, it seems that slow-twitch (and fast-twitch) muscle fibre tends to revert back to its pre-training status after a period of inactivity (although aging may provide an exception to this rule, as we shall see later). In fact, the theory is that muscle fibre has a fast-twitch default setting. This is entirely logical: since we use our slow-twitch fibres much more than our fast-twitch ones on a daily basis, a period of inactivity would de-train slow-twitch fibre and allow fast-twitch fibre to regenerate and convert back to a faster contraction speed. The interesting and slightly less logical aspect of this process is that it does not necessarily require speed training, as demonstrated by research on muscle tissue rendered inactive by accident or illness. [7]

When it comes to recruiting winning muscle, it is impossible to overlook the vital role of the brain. Muscle fibre can only function at the behest of our brains, and it is possible that athletes 'learn' how to tolerate the pain associated with lactate build up, for example, and consequently become better able to recruit their muscle fibres.

Recently, research has begun to appear on the so-called 'central governor', which is seen to be the determinant of the body's ability to sustain endurance activity by tolerating increasing intensities of exercise. It has been argued that the governor's setting can be altered through the experience of intense exercise and a corresponding shift in willpower to permit greater endurance perseverance. This theory has been substantiated by evidence that muscles can still hold onto 80 to 90% of ATP and some glycogen after intense endurance efforts – *ie* when the athlete has 'decided' to stop exercising.
It has been suggested that the body – and, for our purposes, its muscles – will always

hold onto some crucial energy-producing materials, just in case it is called upon to react in an emergency. This is seen as a legacy of the unpredictable past that confronted our prehistoric ancestors, who never knew if they would need a bit more energy to flee from a sabre-toothed tiger after a long day's hunting and gathering!

The central fatigue hypothesis

Closely related to the thoughts on the 'governor' is the 'central (nervous system) fatigue hypothesis', postulating that the brain will 'shut down' the body under certain conditions when there is a perceived threat of damage to vital organs, irrespective of an individual's fitness. The conditions specifically identified to trigger central fatigue are high altitude and high temperatures; although researchers believe it could also swing into play under less taxing conditions.

The famous exercise physiologist and runner Tim Noakes states: 'There is no evidence that exhaustion under these conditions is associated with either skeletal muscle 'anaerobiosis' or energy depletion.... There is sufficient evidence to suggest that a reduced central nervous system recruitment of the active muscles terminates maximum exercise'.

Various methods have been used to try to trick the brain into keeping muscle fibre recruitment going under extreme conditions. With regard to high temperatures, these involve 'pre-cooling' strategies, such as ice baths or ice helmets. These and similar strategies are designed, quite literally, to cool the brain and extend the body's 'heat stop switch' threshold.

As mentioned previously, aging also has an influence on the development of endurance muscle fibre, with fast-twitch fibre declining much more rapidly than its slow-twitch counterpart – by as much as 30% between the ages of 20 and 80.

By contrast, endurance athletes can expect to maintain their slow-twitch fibres and even increase them by as much as 20%, over a sustained training career. The trouble is, though, that without fast-twitch fibres endurance performance will inevitably decline.

In summary, then, developing your endurance capacity relies on a number of adaptations, as follows:

- Enhancing the already high oxidative capacities of slow-twitch fibres
- Improving the capacity of fast-twitch fibres to contribute to endurance activity, taking account of distance and the need for both sustained and 'kicking' power. This process may, in fact, hold the physiological key to optimising endurance performance
- Working on mental strategies to develop increased endurance tolerance and the sustainable contractile properties of all muscle fibre types
- Using pre-cooling techniques to delay physiological shut-down.

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John Shepherd

Continuous and interval training

Continuous training is when an athlete exercises in a steady aerobic way and interval training is characterised by repetitions of work with a recovery period following each repetition.

Continuous training

Continuous training can be broken down into the following sub-divisions which have slightly different effects upon the energy pathways:

- Running at 50 to 60% of maximum heart rate or 20 to 36% of VO_2max. Very easy pace, it metabolises fat and is aerobic. Duration 60 minutes plus. Useful for joggers & ultra distance runners
- Running at 60 to 70% of maximum heart rate or 36 to 52% of VO_2max. Slightly faster pace, it burns glycogen and fat and is aerobic. Duration 45 to 90 minutes. Useful for marathon runners. Improves cardiovascular system and capillarisation
- Running at 70 to 80% of maximum heart rate or 52 to 68% of VO_2max, 10km pace, it burns glycogen and is aerobic. Duration 30 to 45 minutes. Useful for 10km and marathon runners. Improves cardiovascular system, capillarisation and is glycogen burning
- Running at 80 to 90% of maximum heart rate or 68 to 83% of VO_2max. 5km pace, it burns glycogen and is anaerobic. Duration 10 to 20 minutes. Useful for 5km to marathon runners. Improves cardiovascular system, capillarisation, glycogen burning, lactate tolerance and removal
- Running at 90 to 100% of maximum heart rate or 83 to 99% of VO_2max. 800/1500m pace, it burns glycogen and is anaerobic. Duration 1 to 5 minutes. Useful for 800 to 5km runners. Improves glycogen burning, lactate tolerance and removal.

Interval training

Interval running enables the athlete to improve the work load by interspersing heavy bouts of fast running with recovery periods of slower jogging. The athlete runs hard over any distance up to 1k and then has a period of easy jogging.

During the run lactic acid is produced and a state of oxygen debt is reached. During the interval (recovery) the heart and lungs are still stimulated as they try to pay back the debt by supplying oxygen to help break down the lactates.

The stresses put upon the body cause an adaptation including capillarisation, strengthening of the heart muscles, improved oxygen uptake and improved buffers to lactates. All this leads to improved performance, in particular within the cardiovascular system.

Before undertaking interval training a few simple rules should be understood.

- Undertake a period of continuous running before starting interval running
- Consider the various elements of the session and ensure that they are within the scope of the athlete
  - the length of the work interval, longer gives a better effect
  - the pace should be comfortable raising the athlete's heart rate to the required % of MHR (see above)
  - the number of repetitions should reflect the condition and age of the athlete
  - the rest interval should enable the athlete to jog and bring the heart rate down to near 100 to 110 bpm
- Improvements can be made by altering any of the above variables, however the coach should only change one variable at a time
- All changes should be gradual in nature and take place over a period of time
- Ensure the surface to be run on is flat and even. It is usual to do interval training on a track although it can be done on good quality grass playing fields. Roads are not a suitable surface because of the pounding effect.

Circuit training is a common method of interval training

The benefits of interval training

In planning training programmes, controversy still exists as to the optimum duration of the workloads needed to gain maximum results. It would seem, after all, a waste of effort to train for longer periods than actually necessary for the same gain in fitness. In an attempt to address this problem, a research project in Thunder Bay, Ontario, Canada, randomly assigned 21 females, aged between 18 and 26, into two groups before embarking on a seven-week training programme.

The subjects were tested in a laboratory to evaluate their maximum oxygen uptake (VO_2max), ventilator and lactate thresholds, all key indicators of aerobic fitness. All the subjects trained at 85% of VO_2max for the first two weeks, with a

5% increase every fortnight. Thus, they trained at 85% for the first fortnight, 90% for the second fortnight and 95% for the third.

The frequency of training, which continued to exhaustion, was four times each week. Group one trained with 30 second interval workloads, while group two used a two minute workload. Both groups, however, continued with a work to recovery ratio of 1:1.

At the end of the seven-week training programme, the subjects were retested in the laboratory. It was discovered that there was a significant increase in VO_2max, ventilator threshold and lactate thresholds of all subjects. There was, however, no significant difference between the two groups utilising the different workload durations.

This might suggest that there is little difference in using 30-second or two-minute duration workloads, while both forms of workout have strong training effects for aerobic fitness.

The study does not, however, state the initial fitness levels of the subjects, which clearly has an effect upon the possible gains in fitness achievable. Further, the training does not mimic a realistic training programme, where utilisation of different energy pathways should be involved, including the important steady state component of training.

Brian Mackenzie

Power gym training for athletes

When visiting a gym one will find many an athlete doing all sorts of exercises with all sorts of reps and sets. The question is why are you going to the gym and why are you doing resistance training?

When power is your goal, training should be as follows:

Training goal	Load	Reps	Sets	Rest between sets
1 rep	80-90%	1 – 2	3 – 5	2 – 3 min
Multiple rep	75-85%	3 – 5	3 – 5	2 – 4 min

Important to note here is the rest. Many athletes train by rushing the program. This is pointless as it takes 2 to 5 minutes for the neural system to recover from what has just been done. Power training and speed training depends greatly on optimal neural recruitment for maximal performance. Therefore you would train maximally by working according to the recovery time. If you rest less than the 2 minutes the session will become just another endurance or hypertrophy session and little power gains will be made.

Training for power means taxing the neuromuscular system, and with the prescribed rest, the system will have recovered sufficiently to perform another 'fast' action.

Remember, it is important to have a fast action. Therefore make sure the weights that you choose allow you to move it fast. Moving a lighter weight 0.5 sec faster, then a 10kg heavier weight 0.5 sec slower will result in less power developed. Refer to the rationale.

The power exercises

These exercises are often referred to as the explosive, core or total body exercises. Muscles involved are the following: gluteals, hamstrings, quadriceps, hip flexors, core area muscles, calves, shoulders, upper shoulder, upper back and upper arms.

1. Clean (power clean or hang clean)
2. Snatch
3. Push-press or push-jerk
4. Half-squat.

These are by far the most explosive exercises an athlete could do in the gym.

Advanced power gym training

The above mentioned are the traditional methods. Following here are a few modified exercises from the more traditional ones, and are only to be tried with athletes that have mastered the traditional exercises and have a good general strength base.

Squat and vertical jump

After completing a set of 3 to 5 reps of half-squats, immediately do 1 to 3 reps of tuck jumps or vertical jumps. This can also be done with lunge jumps with weights followed by lunge jumps without weights.

Squat jumps

With the bar on the shoulders or dumbbells in hands do 3 to 5 reps of half-squat jumps. Make sure you stabilise to help keep your balance. If unsure and not confident perform this exercise on the seated leg press machine or the hack squat machine.

Bench press throw

With this exercise make sure you have two spotters, one on each side of the bar. Choose a weight of between 30 to 50% 1RM. Lower the bar and push it back up by exploding with it and try to throw it and with the help of the spotters catch it again. This is a very dangerous exercise but very effective. If uncertain, do the bench press followed by a plyometric push up (Start off in a push up position. Lower your body slowly and push off as fast as possible to lift your hands of the surface and 'catch' yourself before you land on your face by landing on your hands again) or do a few medicine ball throws.

Rationale

The secret of power training in the gym is not to move big weights but rather the speed of movement with lighter weights. Consider the following:

Power is all about Watt output

So if you are a female athlete weighing 60 kg, and you lift a 30kg weight into a snatch end position of 1.95m up from the ground in time of 6.2 sec and you're doing 3 reps, your Watt output will be calculated as follows:

Determine the weight of the bar in Newtons

- Weight = $9.8 m/s^2$ x 30kg = 294 N
- Work = 294 N x 1.95m x 3 = 1719.9 J (1720 J)
- Power = 1720J / 6.2 sec = 277 Watt output.

Now consider the same athlete doing the same exercise but using a weight of 40kg x 3 reps in a time of 9.5 sec. (Logically one would think that there should be a bigger Watt output):

- Weight = $9.8 m/s^2$ x 40kg = 392 N
- Work = 392N x 1.95M X 3 = 2293 J
- Power = 2293 J / 9.5 sec = 241 Watt output. (36 Watt output less)

If, however, you could lift the 40kg in less time your Watt output will improve and thus you power. In physics, power is precisely defined as 'the time rate of doing work'.

Although the word strength is often associated with slow speeds and power with high speeds of movement, both reflect the ability to exert force at a given speed.

Science tells us exactly how to train for power. I find it amazing that in this modern day and age some coaches and athletes still persist with lifting heavy weights, which is good, but not having the athletes recover sufficiently blows the mind. Or having athletes perform 3 to 5 sets with repetitions anywhere between 12 and 20 is beyond me.

Les Archer

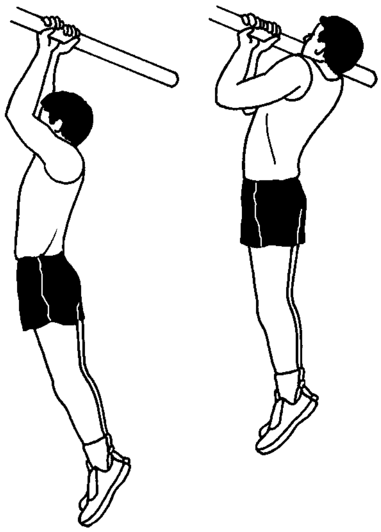
Chins test

The objective of the Chins test is to monitor the development of the athlete's arm and shoulder muscular endurance.

Required resources

To undertake this test you will require :

- Chinning bar
- Assistant.



How to conduct the test

The Chins Test is conducted as follows:

- Hang from the bar with your palms facing your body
- Pull up until your chin is level with the bar
- Lower so as to straighten your arms
- Repeat as many chins as possible
- Record the number of chins

Analysis

Analysis of the result is by comparing it with the results of previous tests. It is expected that, with appropriate training between each test, the analysis would indicate an improvement.

Normative data for the Chins test

Gender	Excellent	Above average	Average	Below average	Poor
Male	>13	9 – 13	6 – 8	3 – 5	<3
Female	>6	5 – 6	3 – 4	1 – 2	0

Table Reference: Davis B. et al; Physical Education and the Study of Sport; 2000

Target group

This test is suitable for active individuals but not for those where the test would be contraindicated.

Reliability

Reliability would depend upon how strict the test is conducted and the individual's level of motivation to perform the test.

Brian Mackenzie

Module 9

Co-ordination

Co-ordination

It is often said that planning training programs is a combination of art and science. One of the most important aspects of sports performance is the athlete being in the best shape at the right time.

This is the case not only for the elite athlete arriving at a major games or championships, but also for the club runner aiming for a special 10K or marathon. Athletes will always want to run personal bests at the races that are most important to them, but to be able to do this the element of risk is removed by yearly planning.

Overview of the articles in this section

- Joe Dunbar in his article ‘Periodisation: plan the perfect peak’ explains how to plan your training by working backwards from the season’s main competition
- John Shepherd examines the use of sport-specific weight training workouts and the effects of combined training on sports performers in his article ‘Weight training and endurance training – the perfect sports conditioning partnership?’

The articles in this section are applicable to most sports.

Periodisation: plan the perfect peak

Various systems of planning the athlete's year have developed over recent decades, most of which form around picking a key event much in advance and working towards such a goal. The event chosen will vary according to the athlete's standard. For the very best, this will indeed be a major championship. For those less confident, it may be the selection race for such a championship, while for those on the level below, it could be a county champs or even a club event. Once the main event is chosen the athlete should start the planning process by working backwards. The structure of the year can then be completed.

One of the most common methods of structuring the athlete's year is by using the process of periodisation. This involves splitting the year up into a number of periods, which themselves may by sub-divided, with various sections of the training process worked on in each particular period. The generalised pattern used is preparation, competition and then transition. By splitting the year up into broad phases, not only does this help the planning of a peak for one particular year but it should also ensure a progressive development over a series of years, so an athlete may reach an ultimate sporting target.

Exactly how the year is divided can depend on a variety of factors, ranging from how many and when competitions are, to how long it may take for an athlete to peak. One of the criticisms of the theory of periodisation that was put forward by Soviet coach Matveyev is that it does not cater for an athlete's individual traits. However, if the planning is done carefully with adaptation for the individual, there is no reason why this should be the case.

The main structure of the year will depend on whether the athlete is going to have just one competitive period or more. More commonly, athletes are deciding to go indoors for extra competition during the winter, and in Britain there is the possibility of athletes having to deal with the Commonwealth Games if they are held in the southern hemisphere, with another peak required in the summer for the European Championships. This does not necessarily create a problem, as long as the planning is correct. If just one peak is required, the athlete is said to have a single periodised year but a double periodised year (or multi-periodised) is used if a second peak is considered.

The preparation period is spent conditioning the body and building up endurance for the season. In Britain, in a single periodised year, this will take the bulk of the winter. The preparation period may be split into a number of mesocycles, within which certain targets may be set in terms of achieving endurance or strength.

Such mesocycles will become more specific to the demands of the sport as the competition period gets closer. So, the first mesocycle will contain far more event specific drills and practices, with running workouts becoming quicker and closer to competition speed.

The structure of the mesocycle may even be split again, forming a series of microcycles, which for convenience often last a week. Most athletes tend to operate on such a basis, with the structure consisting of one long run on say a Sunday, a couple of interval sessions, split up by steady state running, perhaps punctuated with some sessions of resistance exercises. It is important that the demands of the event are all covered within a microcycle. If an athlete has difficulty in fitting everything into a week, then he or she should consider working on perhaps a 10-day cycle; after all it is only tradition that tends to dictate that you should do a long run on a Sunday or train on the track on set club nights.

The amount of time needed in the preparation period will vary between athletes. This is because different athletes need differing amounts of time to reach a peak, which could well vary from 2 to 8 months. The most important part of planning is working out what works for the athlete and then calculating the optimum amount of time needed to be spent on each period. During the preparation period, the work may be general or specific. This may be the case not only in weight and circuit training, but in running as well. This period may, therefore, be split into a phase of general preparation, followed by specific preparation, or the two can be worked on simultaneously if necessary.

The competition phase

Once the preparation period is over, the main competition phase will begin. This phase will be split into a number of mesocycles. The first of these might contain a large element of speed work and competition-specific running, interspersed with some low key races. The emphasis will change in the next mesocycle as more important competition is met in drawing the athlete towards a major peak in the final phase.

At the end of the competition phase the athlete usually enjoys the transition stage. Here it is quite usual for the athlete to have a break from the rigours of hard training. A complete break may be enjoyed, or a period of active recovery may be used, whereby the athlete participates in different sports to maintain a small level of general fitness but will give the body recovery from the specific training it has endured throughout the rest of the year. This period is also the source of a psychological break and is a good time to evaluate the completed year and begin planning for the next. From this position the athlete will be able to build upon the work just completed, so that a progressive development over successive years is enjoyed.

If two peaks are required, the length of the preparation period is considerably cut and a competition period inserted. This will be followed by a second preparation period before the next competition phase.

A variety of theories exists as to whether a single multi-periodised year is better. In weight-lifting, where extensive research has been carried out, the general view is that the athlete is better off taking in two or more competition periods. In runners, however, it has yet to be shown that this would also be the case. It was interesting to note that in 1990, no athlete who competed and won a medal above 400m in the Commonwealth Games in February, was able to win a medal in the European Championships in August. The likes of Peter Elliott, Matthew Yates, Eamonn Martin and lan Hamer, all won medals in Auckland but despite reaching the finals in Split, could not, a little surprisingly, get in the first three. This perhaps highlights the difficulty that distance runners face in performing a double peak when championships are concerned. Many prefer a single periodised year, where they can perform numerous consistent weeks of base endurance training, with perhaps a few outings over cross-country.

Quite how training loads should be structured within the preparation period is also a subject of conjecture. Again much of the research has been performed in the Soviet Union and Germany, with ideas diffusing to the west in the sport of cycling – the Soviet coach Kuznetsov has used uniform training loads throughout the year. Here the load is evenly distributed but has brought about excellent results not only in the USSR but also in the World Championships and Olympics.

Other options, however, are the wave-like distribution of training loads or fluctuating training loads. Such a method is more in line with physiologist Hans Selye's general adaptation theory for training. He proposes that the body receives a stress placed upon it (*ie* a training bout). This he calls the shock. The body then adapts to this, which is the next phase. The body, however, encounters staleness if the same training load is applied. The adaptation theory of Soviet scientist Meerson would support the idea of flexibility of training loads. This similar idea states that the body receives a boost after a period of fatigue from training. The body, therefore, needs a small rest period to be able to cope with a training stress and thus adapt to tolerate a greater workload. This theory of super-compensation has been well accepted in the Soviet Union and forms the basis of many of their exercise programs. One advantage of fluctuating training loads is to give the athlete variation, which may in turn help motivation.

The research work that has come from the east deals very much with strengthening exercises. A paper from the USSR (*Legkaya Atletika* 11:4-5 1987. translated in the Soviet Sports Review) shows the results of extensive research and suggests how strength training should be structured in the year of the distance runner. It is extremely precise in its contents relating to seven strength exercises that should be used, for example, leg press and barbell squat. Tests of strength in each of the exercises are performed at the end of the transition period and these maximum levels are termed as 100%.

The paper then suggests six stages which fill the athlete's year, each having specific targets. At the start of the preparatory period (60 to 80 days) the relative strength (the maximum weight lifted divided by bodyweight) in the leg exercises should increase by 120 to 125%, while the strength endurance (the number of repetitions at 50% of max) should rise to between 130 to 140%.

In the second stage the strength endurance should increase to around 220 to 240%, while relative strength should not fall below 112%. During the competition phase, the third stage, the strength endurance should be maintained at 240 to 250%. The fourth stage is the second preparation phase lasting 50 to 60 days. Here they suggest that relative strength is increased to between 120 to 125% and strength endurance should rise to 250 to 280%. The pre-competitive stage should see a rise in strength endurance from 300 to 350%, while in the sixth phase, the competition stage, which probably lasts 120 to 150 days, strength endurance should be maintained at 250 to 300% and relative strength at 108 to 115%.

This very structured program, of course, assumes an indoor season but shows the level of planning, with targets that they feel necessary for correct overall strength development.

The above research may seem complex in nature but the points made have been backed up by extensive research. In planning for the athlete, it must always be remembered that each individual is different and will have varying requirements. The coach and athlete must, therefore, examine the demands of the event, train according to these with set targets for each training phase in mind. The best results can only come if the peak event is chosen in advance and the planning is worked backwards from this. So, if you really want to run a PB on the big day, consider a long-term plan.

Joe Dunbar

Weight training and endurance training – the perfect sports conditioning partnership?

Weight training and endurance training appear to be two halves of a perfect sports conditioning marriage. But, as with any good relationship, there will always be the occasional conflict and element of discord.

Let us begin with the logical assumption that weight training benefits endurance athletes, by focusing on the sport of rowing. Rowing requires an anaerobic contribution of about 30% to the 2k Olympic race distance. In consequence, rowers often train their lactic anaerobic systems with high-intensity, short duration intervals (lasting from 30 seconds to 5 minutes), with very short – often 1:1 – recoveries. These workouts target slow and fast-twitch muscle fibres – the latter providing much of the power needed for these turbocharged efforts.

Logic says that weight training these fibres will be beneficial, especially when you consider that the actual rowing race is completed in about six minutes, using 200 to 240 plus strokes – an amount of ‘repetitions’ that could easily be accrued in a standard power (70 to 80% of 1 repetition maximum) weight-training workout, comprising 4x10 repetitions of 6 exercises.

However, logic does not always apply, and this type of weight training (and indeed other types) may actually offer little direct benefit to rowers when it comes to improving their endurance. Bell and associates looked at the effects of three different weight-training programs on 18 varsity rowers during their winter training. [1] One group performed 18 to 22 high velocity, low-resistance repetitions, while another did low-velocity, high-resistance repetitions (6 to 8 repetitions) and a third did no resistance training at all. All resistance exercises were rowing-specific and were performed on variable-resistance hydraulic equipment 4 times a week for 5 weeks, while the subjects continued with their normal endurance rowing training.

Which group's rowing improved the most? When subjects were tested on a rowing ergometer the researchers found no difference between any of the groups in terms of peak power output or peak lactate levels. So the weight training apparently served no purpose. Similar findings emerged from a US study, when elite male weight-training rowers displayed no increase in VO_2max by comparison with a rowing-only group, who improved their VO_2max by up to 16% during pre-season training.[2] So, it looks like our happy couple's relationship is not off to a very good start!

Before we start to consider why this might be, let's take a look at some more research from different sports. Tanaka looked at the effects of weight training on 24 experienced swimmers over 14 weeks of their competitive season.[3] The swimmers were divided into two groups of 12, matched for stroke specialities and performance; one group performed weight training three days a week, alternating this with their swim workouts, while the other group did no weight training at all and just continued swimming. Both groups trained for 8 weeks.

Weights – both fixed and free – were selected for their swimming specificity, with the swimmers performing 3 sets of 8 to 12 repetitions on lat pull-downs, elbow extensions, bent arm flies, dips and chin-ups. The weights were progressively increased over the duration of the training period, with a tapering period two weeks before their major competition.

What was the result? As with the rowing studies, weight training failed to improve performance, despite the fact that swimmers who combined resistance and swim training managed to boost their strength by 25-35%.

Weight training for skiers

So are our weight-training-and-endurance couple buckling under the pressure of their ill-assorted union, while putting on a brave face and continuing to work together? It looks like divorce is on the cards, especially after a certain Mr

Paavolainen's evidence is taken into account. He and his co-workers considered the effects of weight training and other power-training methods on the performance of cross-country skiers – long considered the ultimate aerobic athletes.[4]

Seven skiers performed power weight-training exercises (at high velocity against a moderate-to-high loading) as well as plyometric (jumping-type) exercises for three weeks, while another group of eight skiers performed strength-endurance high-repetition training for the legs and arms. Both groups also continued with their normal endurance training. At the end of the study period, the researchers found no difference in measures of endurance capacity, such as VO_2max and anaerobic threshold, between the two groups. In short, the various weight and plyometric training sessions had not enhanced skiing performance power.

Our perfect weight-training-and-endurance couple seem doomed to disharmony and incompatibility. But could there be some mitigating circumstances? Tanaka introduced weight training into the competitive phase of his swimmers' training cycle – perhaps not the best time. It is possible that, at this stage, the swimmers' performances could have been impaired rather than improved by the added training load.

The relevance of maximum strength

Paavolainen's plyometric power training cross-country skiers did increase their ability to express peak power, although this is not much use to these athletes, whose prime requirement is a highly-developed aerobic system. It may be, as exercise scientist Saziorski suggests, that since cross-country skiing is an ultra-endurance sport, weight training has little direct relevance to performance in the first place [5]. Saziorski believes that maximum strength is of little importance in sports with a maximum strength requirement of less than 30%.

The rowing findings are more difficult to explain, but there is a possible answer. It is argued that when an endurance athlete reaches a certain level of performance strength – which can be developed through their everyday CV training or with weights or other resistance training – further improvements in weights-based strength will not bring about further improvements in performance. Since the rowers in the above-mentioned studies were all performing at a high level already, it could be argued that they already had more than enough 'performance' strength, developed through years of correctly-executed rowing technique.

Shepard offers a very succinct explanation for why weight and endurance training can make for poor bedfellows [6]. 'Some of the most important and influential factors that result from physical conditioning occur at the cellular level in the muscles, that is, the majority of training effects are peripheral,' he explains. 'The number and size of mitochondria, the amount of myoglobin, the amounts of ATP and CP that are stored, and the concentrations of key enzymes associated with particular energy systems are increased. Training is specific and selective of the types of muscle fibres used. That selectivity will determine the nature of training effects and the type of performance that is improved.'

Essentially what he is saying is that training different energy systems at the same time can produce a confused physiological state – the so-called 'interference effect'. How can pure high-power fast-twitch type IIb muscle fibre be expected to gain in size and power-generating capacity through weight training if it is being relentlessly bombarded in the same training phase – indeed the same workout – by extensive long, slow distance work or intense interval training? Training that, while bolstering its type I slow-twitch counterparts, also causes its type IIa cousins (which generate intermediate power) to defect to the slow endurance side? Depending on the training stimulus, all these muscle fibres can become orientated more towards endurance or power/speed.

So here is the million dollar question: is there any real benefit to be gained from weight training if you are an endurance athlete? To determine this for yourself, you need to look at the specific strength requirements of your sport. If you're a cross-country skier or marathon runner, weight training may not be relevant to improving your performance as you cannot construct a session in the gym that directly replicates what you'll go through in a race.

However, weight training used in combination with other types of resistance training should not be discarded: marathon runners, for example, should expect to improve their performance by improving their foot strike; they can achieve this through plyometric and running drills, and specific weights exercises like the split squat and lunge. The key for them – and for similar endurance athletes – is to construct a training program that channels their resistance-training gains into strength that will improve their technical performance.

Circuit training for endurance

Circuit resistance training (CRT) has been shown to offer a great deal to endurance athletes as it targets type I muscle fibre, can develop VO_2max and lactate threshold and will also have a limited effect on increasing strength. For best results, use a weight set at 50 to 60% of 1RM, since this seems least likely to interfere with the development of enhanced endurance capacity.

You may have noticed an apparent contradiction in that some of the studies quoted earlier did actually use CRT-style training, but to no effect in terms of improved endurance performance. This can be explained with reference to the training variables of order and recovery.

The studies by Tanaka and Paavolainen, for example, simply threw all the training ingredients together into the workout mix without taking order and recovery into account.

Taking training unit timing into consideration, Sporer et al looked at the effects of weight training on aerobic/anaerobic CV performance in 16 male collegiate athletes [7]. The aim of the study was to see whether the type and intensity of aerobic training affected concurrent weight training after 4, 8 and 24 hours of recovery. One group performed steady state work at 70% of maximum heart rate, while the other performed 95 to 100% intervals with 40% MHR recoveries. Both groups were then subjected to 1RM maximum strength testing on bench press and leg press.

The researchers found that for both groups weight training gains were compromised by the endurance work unless adequate rest was allowed. More specifically, the participants' leg muscles were negatively affected by their aerobic training in the leg press test, although bench press performance was unimpaired. In consequence, they made the following recommendations for athletes performing concurrent training:

- If you must perform both workouts within a single day, allow at least eight hours between aerobic training and strength training
- Lower-body strength training should not be performed on the same day as aerobic training.

Expanding further on these suggestions, you could also consider developing strength in a specific training cycle, removed from your endurance training. This might be particularly helpful at the beginning of the training year, when you could gain most. Such a strategy could reduce the interference effect and provide the optimum conditions for developing stronger, fatigue-resistant muscles. Periodic returns to weight training micro-cycles could then be used to 'top-up' strength levels.

Under such conditions, Canadian researchers found that a group of rowers who strength trained for 5 weeks before 5 weeks of endurance training were rewarded by a 16% increase in VO_2max and a 27% improvement in lactate tolerance [8]. By contrast, rowers who trained in the reverse order boosted VO_2max by only 7% and showed no improvement in lactate tolerance.

The explanation

The strength-before-endurance group gained quality rowing muscle without compromise, and were able to use it to row harder and faster, with greater fatigue-resistance, during endurance training. Working out for weight training gains alone may have enabled them to push beyond their 'normal' previously conditioned rowing power levels.

Finally, if you are an endurance athlete you should use weight training to avoid injury, since it is almost beyond dispute that weights and resistance training exercises can protect against injury by strengthening soft tissue.

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