The World

Sports Science Training Workbook

Level 2

Editor

Brian Mackenzie

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The World Sports Science Training Workbook

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In 2003 *The World Sports Science Training Workbook* was launched to fill a crucial gap in the provision of training advice for athletes and sports people.

Now, a year later the book has done far better than I ever imagined. It has sold so many copies it has become the most popular workbook in its field and is being used in the training of many up-and-coming young stars.

Due to it success my publisher commissioned me to compile a second workbook – *The World Sports Science Training Workbook Level 2*, to take the concept to the next level so as to move the reader up to competition level in their chosen activity as quickly and efficiently as possible.

Ideally, the two books should be used together. The first to set up your basic understanding of the many components related to training, and then the second volume will show how to lift your performance to its ultimate competitive level.

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.

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. I'm delighted to say these training workbooks have solved the twin problems of cost and inconvenience in obtaining expert coaching guidance.

You now possess, at the click of a button, the key to an exponential leap in the many aspects of training from endurance, speed, strength to nutrition and psychology.

Please let me know how you get on!

Best wishes

Brian Mackenzie
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Planning

Introduction

Look at almost any training schedule in this country and it is odds on that it will revolve around a seven day cycle. This is not surprising as most athletes and coaches find it convenient to work in weekly blocks. Nothing wrong with that, you may think, and there may well not be, but to cover all aspects of fitness and training in a week, you may find that you are putting in either too many sessions, or not allowing sufficient recovery between them. The end result is that you may not perform all the sessions that you would like or need.

The planning of training is often done in a cyclical fashion, starting with the larger yearly cycle. This can be broken down to smaller cycles that correspond to a large training phase, such as early season conditioning in winter, or the competition phase in summer. Such medium sized cycles are then split into smaller micro-cycles and it is these that are usually conveniently packaged into a seven day week. But it appears there is little reason for this, apart from habit.

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. 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.

Overview of the articles in this section

- Joe Dunbar examines the training requirements for rowers
- Raphael Brandon explains how rugby players should train to reflect the varying energy demands of their field sport
- Derek Parker provides advice on appropriate training that will help make you a winner on the cross country circuit
- Joe Dunbar examines the training requirements for swimmers

The articles in this section are applicable to specific sports but the approach to planning, described in these articles, can be applied to all sports.

Get out of the gym and on to the water!

Demands of the sport

There used to be a strong belief in rowing that you had to be a big, powerful, anaerobic beast to do well. This was fuelled by the fact that most successful rowers were, indeed, of a bigger build with hulk-like musculature. Such athletes trained extremely hard but not necessarily according to the demands of their sport. Given that the race distance is 2000m, which typically takes about 6 to 7 minutes to complete, depending on crew size, gender and, of course, ability, it is more accurate to think of rowing as a power endurance sport rather than a strength sport.

Obviously great strength is needed to generate large force and propel the boat at high speed. Yet the more pertinent factor for you to consider, as a coach or athlete, is the length of time taken to compete. It has been shown physiologically that at least 70% of the energy requirement comes from aerobic metabolism. The remainder comes from anaerobic sources, a small portion of which is alactic in nature. Just by looking at this physiological breakdown it is easy to see that there must be plenty of work done to condition the aerobic, or cardio respiratory system because however large and powerful a rower or crew, if they lack sufficient endurance, they'll remain in full view of the opposition in the closing stages of a race!

Phases of training

Much of your 'conditioning' work will be done in the winter months when you will be rowing heavy mileages. It is not uncommon for a large part of this work to be done on a rowing ergometer rather than the water, because of light and water conditions. The intensity of this work has to be low, because if your volume of training is high it is impossible to do it at a hard level. The trend in British rowing has followed German examples, where extremely high volumes of training are used at low intensities. It is this type of work that is said to increase the oxidative capacity of the muscle cells. This long duration, low intensity work will also enhance your ability to burn fat, so if you row in the lightweight category it will give an added advantage.

German physiologists quote percentages in excess of 90% for this type of training in the early winter months, and since the German success rate is good British coaches have followed suit and changed the emphasis to long, slow training. Percentages, however, can be a little deceptive, because although it may look as if very little quality work is performed in the winter months, the actual amount of time of faster work in terms of minutes may not be much different from the summer. The reason is simply that the overall volume of training is far higher in winter than towards the competition period.

Any successful training regimen will have work of a variety of intensities throughout the whole year. It is just the change in emphasis of these levels that alters. Threshold work should be performed through the year until a couple of weeks before competition time. This gives the cardiovascular system an excellent workout. Similarly, you should be performing high intensity repetitions throughout the year to boost your VO_2 max. As with all sports, however, the volume of work must taper down towards the competition period, by when all the hard work must have been done. Maintenance work is still essential during the competition period, so the odd long paddle is needed to work on the aerobic capacity of your muscles, while quality work, used sparingly, can help maintain peak condition.

The training week

There has to be a good mixture of training sessions throughout the week and, as I mentioned above, the exact structure will depend on the time of year. The long paddles will form the bulk of your mileage, but quality work can be structured in a variety of ways. Longer pieces at a higher level (ideally controlled by heart rates) can form threshold work. The pace will be slightly lower than race pace but the duration longer, *eg* 20 to 25 minutes. This can also be split to reps such as 4 x 5 to 6 minutes, 3 x 8 minutes or 2 x 10 minutes. Progression can be achieved by increasing the pace at which you travel, as long as you stay in your set heart rate range.

Shorter, more intense training can be used to work on the anaerobic aspect of performance, as well as technique. Such sessions are more frequent in summer but should not be neglected during winter months.

Strength training is another important area that needs year-round attention. Naturally the muscles used in rowing need to be strong, but the muscles of posture, which may not get well trained in the rowing action, also need toning to avoid imbalances. Many rowers perform strength training in circuit fashion but the value of such work has to be questioned. First, if increase in strength is the goal, the load should be high, the reps low and the recovery sufficiently long. This is rarely the case in rowing training, where lots of repetitions from one exercise to the next, with little or no recovery, is far more usual. Some might argue that this works on strength endurance, but a more pertinent counter argument is that the most specific way to work on strength endurance is on the water.

Second, it has to be remembered why these traditional circuit training sessions were first introduced a couple of decades ago. When rowing was lost due to bad light or weather, circuit training was the next best alternative because it gave a good aerobic workout by keeping the pulse raised for a sustained period. Nowadays ergometers are available for rowing so the customary circuit session has less value. It is also fair to say that they may well replace running and cycling, two forms of cross-training that have remained popular from pre-ergometer days. After all, the training that is most likely to improve your rowing performance is… more rowing!

Perhaps it's time for rowing coaches to rethink the philosophy behind some of their training sessions. By keeping workouts specific and effective, they could take performances to a new dimension in the 21st century.

Joe Dunbar

Planning the training for rugby

Introduction

Sports scientists classify team sports like rugby as 'intermittent sprint sports' because, in the course of a match, players will alternate between sprinting, running, jogging, walking and standing. Rugby matches are like random interval workouts and include sport specific activities such as rucking, mauling and scrummaging. These are game specific tasks and like sprinting they are high intensity activities. When rugby players perform these high intensity activities, their anaerobic systems provide the required energy, while the aerobic system predominates during the low intensity activities.

Energy Pathways

If the high intensity periods are short, less than 10 seconds, and recovery times between efforts are relatively long, 60 seconds or more, then the phosphocreatine

(PC) system will be the key energy source. This is the simplest and most rapid means of energy production, in which phosphate (donated by PC) and Adenosine Diphosphate (ADP) combine to make Adenosine Triphosphate (ATP). During the low intensity periods, the aerobic system will replenish PC stores, ready for the next high intensity effort.

However, PC stores can provide energy for only about 10 seconds of activity. So, if the high intensity periods are of intermediate length, 10 to 45 seconds, or the recovery times are relatively short, 20 to 40 seconds, then the glycolytic system of anaerobic energy production, involving the breakdown of carbohydrate within muscle cells to release energy, comes into play. Similarly, short periods of high intensity work, interspersed with recovery times that are too brief for complete replenishment of PC stores, also bring the glycolytic system into play.

Demands of player position

To understand the key physiological demands on the players, so that we can help them train for top performance, there are two interesting questions about rugby:

1. What is the ratio of high intensity to low intensity activity?
2. Does the work/rest ratio vary with player position?

Research conducted in New Zealand analysed the time and motion of 29 top class professional rugby union players during the course of eight professional 'Super 12' matches in New Zealand.

Players were placed into one of four positional groups:

- Front row forwards (props and locks, or numbers 1,3, 4 & 5)
- Back row forwards (hooker, flankers and no 8, or numbers 2, 6, 7 & 8)
- Inside backs (fly half and centres, or numbers 10, 12 & 13)
- Outside backs (wingers and full back, or numbers 11, 14 & 15).

The hooker was placed in the back row group as they have a roving role at line outs and do not push as much in the scrum as other front row forwards. The scrum half position was not analysed. One or two players from each positional group were analysed during each match.

The researchers broke down player movements as follows:

- low intensity activity
- standing still, walking, jogging, side and backwards stepping
- high intensity activity
- running, sprinting, rucking, mauling, scrummaging and tackling

They then analysed the amount of time spent in each category of movement and the frequency and average time of each individual activity. The key data is summarised in the table below.

	Front Row Forwards	Back Row Forwards	Inside Backs	Outside Backs
Average high intensity efforts per match	128	113	51	46
Average duration of high intensity effort	5 seconds	5.2 seconds	4.2 seconds	5.2 seconds
Average duration of low intensity effort	35 seconds	37 seconds	88 seconds	115 seconds

As you can see, both front row and back row forwards complete many more high intensity efforts per match than backs, with front row forwards performing over three times more than outside backs. While the average duration of high intensity efforts are similar, at around five seconds, across all four positional groups, the average rest periods for the forwards are significantly shorter. Since both sets of forwards only get to enjoy around 35 seconds of recovery, their PC stores will not be replenished and so the glycolytic energy system will be very important for maintaining the work rate required.

Backs, by contrast, get plenty of recovery time between high-intensity efforts, 88 to 115 seconds, which is easily enough time to replenish PC stores. The PC system will, therefore, be most important for backs.

The researchers also found that the type of high intensity activity varied between positional groups. Of the different types of high intensity activity, front row forwards performed fewer sprints, while backs performed more high intensity runs and sprints. Back row forwards and inside backs completed an average of seven sprints per match and outside backs an average of 11.

By contrast, forwards were involved in many more rucks, mauls and scrums than backs. Front row forwards, for example, were involved in an average of 75 rucks/mauls and back row forwards in 57, while inside and outside backs were involved in only 11 and seven respectively.

Conclusion

This data leads to the following conclusions about the key differences between forwards and backs:

- Forwards have to complete more high intensity activity than backs, with shorter periods of low intensity activity between them, which means the anaerobic glycolytic system is of prime importance for them
- The type of high intensity activity forwards perform tends to be 'physical work', *eg* pushing

- Backs perform less high intensity activity than forwards, with sufficient rest between efforts for the PC system to predominate
- Running and sprinting are the commonest high intensity activities for backs

Interval training for anaerobic fitness

Clearly, forwards need to develop good anaerobic fitness, specifically targeting the glycolytic system. The best way to train this system is through interval training, making sure that work periods are sufficiently long, 20 to 40 seconds, and rest periods long enough to allow athletes to repeat the work but not recover completely, 40 to 90 seconds. For example:

- 10 x 200 metres fast running, with 60 seconds rest.

However, as forwards tend to perform more high intensity 'physical work' than running, performing intervals on a rowing machine might be a better. For example:

- Five sets of 4 x 200 metres fast rowing, with 30 second rest between repetitions and 2 minutes between sets

Even more specific to the demands of match play would be interval workouts that combine 'physical work' with running. This would prepare players to work intensively and make appropriate transitions between upper body/trunk strength tasks and running. Players could work in pairs to push or wrestle with each other and then run a fixed distance, with the combination of push/wrestle and run counting as one interval repetition. For example:

- 20 x 5 seconds of push/wrestle + 50 metres shuttle run, with 30 seconds rest between repetitions

This kind of workout would provide a close match of both the energy system and physical task demands of forwards' match play.

Backs, by contrast, need high anaerobic power, targeting the PC energy system. Interval training is also a very effective route to PC fitness, but the work intensity must be higher and the rest periods longer than with intervals targeting the glycolytic energy system; 5 to 8 second repetitions and rest periods lasting a minimum of 60 seconds would be highly appropriate. For example:

- 10 x 50 metres sprints with 90 seconds recovery

For backs, this sprinting workout would be highly sport specific, reflecting the amount of high intensity running they perform in matches.

Aerobic

Aerobic fitness is important for both backs and forwards, since the aerobic system will provide most of the energy for movement and replenishment of PC stores during all low intensity activities. Forwards will also use their aerobic systems to provide energy for the longer high intensity or shorter recovery periods, providing valuable back up for the anaerobic glycolytic system.

As far as aerobic endurance training is concerned, the rowing machine may still be the best activity choice for forwards, with running best for backs. A combination of continuous steady state training and interval workouts would be an effective approach. For example:

- 20 minutes running or rowing at 75% of max heart rate, or 10 x 400 metres running with 60 seconds rest, or 6 x 500 metres rowing with 2 minutes rest

More specific workouts could be developed by performing shuttle runs instead of straight runs as intervals to increase the agility running component for backs. In addition, sessions incorporating circuit exercises to develop pushing and wrestling strength would be useful for forward players.

Raphael Brandon

Training for Cross Country

The high aerobic demands of cross-country running mean that you will have to put in the miles in training if you want to do justice to yourself. This will include lots of steady running to develop a sound aerobic base, improve cardiac output, assist capillarisation (the oxygen carrying capacity of tiny blood vessels in the cardiovascular system) and train the body to convert chemical energy in the form of stored glycogen in the muscles and liver into the mechanical energy which stimulates the efficient, rotational movement of the arms and legs around the shoulder and hip axes.

Aerobic endurance is not just acquired by steady running. It can be developed by running long repetitions at 5K/10K pace with short recoveries. Remember not to run too fast during these aerobic intervals; otherwise you will defeat the objective of the session by accumulating lactic acid and oxygen debt.

Typical aerobic interval sessions include 6 x 1000 metres at 5K pace with 60 to 75 seconds recovery, or 6 x 1600 metres at 10K pace with 45 to 60 seconds recovery. Note that the 10K repetitions are longer and recoveries shorter than those used at 5K pace. This is because the tempo is slower and the aerobic content higher (90% in 10K sessions – 80% in 5K sessions).

Your weekly schedule will also require short steady runs at a pace just below the onset of lactic acid threshold. These will be of approximately 10 minutes duration at slower than 5K but faster than 10K pace. The object of this type of workout is to improve your capacity to run at a fast steady-state pace without incurring the development of lactic acid, which is caused by the oxygen requirements of a given effort being greater than the oxygen extracted from the air inspired by the lungs. Oxygen debt and lactic acid reduce the contractile efficiency of the muscle groups responsible for motion and eventually result in the athlete slowing down and coming to a stop.

A second vital factor

Another essential ingredient of your cross-country schedule is hill running. As well as benefiting the cardiovascular system, this develops leg strength and the muscular endurance necessary to keep going in races when clinging mud and steep inclines start to take their toll of energy reserves.

Over a three week cycle you could run

1) Long hills, *eg* 6 to 8 x 3 minutes sustained effort uphill with a brisk jog-down recovery
2) Short hills, *eg* 12 to 20 x 30 seconds uphill sprinting with slow jog down recovery
3) 800 metres uphill/shallow downhill circuit x 6 to 8 repetitions with 1 to 3 minutes recovery.

The remainder of the training schedule should include rest days and easy recovery running to allow the regeneration of mental and physical energy resources as well as consolidating training gains.

Try to do some of your running off-road on woodland trails, park paths, canal banks, and over the country. As well as protecting your muscles, ligaments, tendons and joints from a constant battering from hard unyielding road surfaces, this gives you a feel for the country and teaches you how to negotiate areas of mud, soft ground, forest tracks, and uphill and downhill sections as economically as possible with the lowest possible energy expenditure.

A typical elite training week

The precise format of the weekly program will depend on your age, fitness, health, experience and stage of training and racing cycle. The amount of work that can be done by a top-class athlete is shown by a typical training week for one of my athletes.

- **Sunday:** 12 to 15 miles steady cross-country run with club members
- **Monday:** (a.m.) 30 minutes easy; (p.m.) Club fartlek – 1 minute at 1500/3K pace (60 seconds jog recovery) to simulate fast start during race + 8 x 3 minutes at 10K pace (60 seconds jog recovery) to develop aerobic capacity + 1 minute at 1500/3K pace or faster to simulate fast finish
- **Tuesday:** (a.m.) 30 minutes easy; (p.m.) 20 to 30 minutes lactic-acid response steady run
- **Wednesday:** (a.m.) 30 minutes easy; (p.m.) 10 miles steady road run
- **Thursday:** (a.m.) 30 minutes easy; (p.m.) Track session – 12 x 400m (25

to 30 seconds recovery) at 3K/5K pace + 1 x 200m 30 seconds after final 400m to simulate race sprint finish, OR 6 x 1000m at 5K pace (60 seconds recovery), OR 8 x 800m at 5K pace (45 seconds recovery)
- **Friday:** (a.m.) 30 minutes easy; (p.m.) 30 minutes steady
- **Saturday:** (a.m.) 30 minutes easy run; (p.m.) 6 to 8 x 2.5 minutes uphill on road or country (brisk jog-down recovery) + 2 miles warm-up + 2 miles cool-down

And for younger athletes

A suitable program for younger athletes is this typical week's training.
- **Sunday:** 60 minutes cross-country run
- **Monday:** 4 x 800m on flat-uphill-flat-downhill-flat road loop (2 minutes recovery) + indoor circuits, *eg* press ups + sit ups + half squats using own bodyweight x 3 x 20 seconds work/ 20 seconds rest with 2 minutes rest between exercises
- **Tuesday:** Rest
- **Wednesday:** 20 to 30 minutes steady road run + indoor circuits, *eg* press ups + sit ups + squat thrusts or burpees x 2 x 30 seconds work/30 seconds rest with 2 minutes rest between exercises
- **Thursday:** 8 x 400m track session at 3K pace (45 seconds recovery) OR 10 x 300m at 3K pace (35 seconds recovery)
- **Friday:** Rest
- **Saturday:** 3 to 4 miles steady off-road run

Ten winning tips

Intelligent training for cross-country is of paramount importance but equally vital is your pre-race preparation in the days, hours and minutes leading up to the event and, of course, what you do during it. Here are ten tips to help you get the very best out of yourself in competition.

1. Taper down ten days before a major competition. Your final hard session should be the second-last Thursday before a Sunday competition or the second-last Wednesday before a Saturday race. This will conserve your body's glycogen and haemoglobin reserves and sharpen you up mentally and physically. The final two days before competition should consist of complete rest or easy running to ensure you line up in peak condition.
2. Try to visit the course before the race – especially if you aspire to a high placing – or find out as much about it as you can from the athletes who have competed there. Remember, though, that other people's opinions about the severity of terrain and hills might differ from yours. What is easy or level ground to one athlete could be hard and hilly to another. But it does no harm to canvass opinions and treat the feedback objectively.
3. Long-term planning should take weather into consideration. Find out the direction of the prevailing wind and climatic factors about the race venue such as its susceptibility to rain, frost, snow and cold. These factors

will determine what you wear, your choice of running shoes, length of spikes, and your tactics. Remember there can be quite marked climatic differences between the north and the south of Britain. To be forewarned is to be prepared.

4. Pack your kit the night before the race and get to the venue at least two hours before it starts. This allows you to have a light carbohydrate snack and enables you to collect your number without having to rush about at the last minute expending nervous energy in long queues.

5. Arriving early gives you time to walk around the course before your event and get to know its every intricacy. Familiarise yourself with its undulations, sharp corners, single-file pathways, and hazards such as drooping branches, tree roots concealed among fallen leaves, trail markers half-hidden in long grass, and protruding fence posts. Identify wet, muddy areas but remember this: a course which is firm and dry during your inspection can become a veritable quagmire if the weather changes or after hundreds of athletes in earlier races have churned it up. Make sure you know the lie of the land over the final 800 metres to enable you to plan your finishing effort, and follow the line of least underfoot and wind resistance.

6. Make sure you have your number, vest and shorts on beneath your tracksuit or waterproofs before you line up for the start. Incredible as it may seem, a number of athletes, including internationals, have been known to discover essential items of wearing apparel missing just before the starter's pistol was due to go off.

7. If you are aiming for a high place, you must be well up with the leaders right from the gun. Although this inevitably means setting off a faster than steady pace, it is a tactical necessity if you want to avoid being well adrift of the leaders and blocked in by a number of runners on single-file paths or narrow parts of the course. You can be sure the pace will settle down after the first 800 metres or so once the athletes have sorted themselves out and established their places in the pecking order. Run within reason and avoid setting off at a suicidal pace! If, like most of the competitors, you are not among the elite, your best ploy is to run at a steady pace from start to finish as this conserves energy. This is more economical and prevents you from incurring oxygen debt or lactic acid.

8. Once the race gets under way, try to avoid getting stuck behind a mass of runners in single-file situations. This may mean having to increase the pace for up to 100 metres to get into a more favourable position. Keep to the drier, firmer parts of the course as far as possible since this is obviously more economical and conserves energy that is otherwise lost in extracting your feet several times from heavy, clinging mud. If you have to run through muddy areas, keep to grassy tufts, make minimal ground contact, lean forward a little to distribute your bodyweight more evenly, and remain mentally relaxed by visualising yourself floating and gliding over the surface like a deer crossing a marsh.

9. If you are competing in a team race, do your best to finish ahead of as many rivals as possible. Even if you are well down the field, you can still make a contribution to your own team's success by picking off rivals in the closing stages. It is amazing how often championship events end on tied scores and the eventual race outcome is decided by the performance of the lower-placed scorers.

10. Obtain a copy of the race results and evaluate your performance. Analyse your race subjectively and objectively with your coach and identify your strong and weak points and how you felt at various stages of the race. Intelligent evaluation of races provides you with vital information to plan further training sessions and set targets for your next competition.

Derek Parker

Swimming – planning the perfect peak

The sport of swimming demands athletes and coaches who are very meticulous in their preparation for competition. In no other sport is the level of preparation, tapering for the big day and rigid control of training intensities quite the same. One aspect that contributes to this accuracy in training pace is the uniformity of conditions. Apart from having a warmer or colder pool or one that is 25, 33.3 or 50 metres in length, there is little difference in the training environment. Let us face it; you are all staring at a black line on the pool floor for length after length.

Demands of the sport

There can be variety within the sport, however, depending quite simply on which stroke(s) are your best and you use in competition, as well as on what distance you travel on race day. This means that there is an element of specialisation in swimming, much as Linford Christie and Rob de Castella have somewhat diverse approaches to running. A 25 metre swim would give a similar competition time to the 100 metre sprinter, while a 200 metre effort could require between 1½ to 2 minutes, and an endurance event of 1500 metres may require between 14 to 20 minutes, depending on age, standard and gender.

This range of events means that a variety of forms of conditioning are needed to match the demands of the race event. Although a training regimen of mixed paces will be used by all swimmers, the sprinter will clearly be logging fewer but faster training lengths for preparation, while the endurance counterpart will log considerably more lengths at a more sedate tempo.

Phases of training

Planning the perfect peak, to coincide with the most important gala on the yearly calendar, is the hallmark of the world class swimmer and coach. The training year will typically start from the active rest enjoyed at the end of your previous season. The planning of various training phases, however, will work back from competition day of the following season. The key variables to play with are volume and intensity, while the influence of land work, especially strength training, will also sculpt your swimming fitness for a crescendo on the important race day. This could be anything from the Olympic Games (in which case a full peak would not be possible for the trials) to a national championships, county championships or local gala or club event. You must choose when your own big goal performance is to be.

It may be that you plan two peaks, one for the short-course season in winter and another for the long course. This double periodisation could mean that you have two general endurance periods, two specific endurance periods, the two competition periods, as well as two taper periods, all within a year. Naturally these periods will be much shorter than in a single periodised year.

How you structure your training within these periods is a matter of preference, but there will probably be greater volume in the general endurance period, followed by a period of moderate to high volume with increased intensity. This is then followed by a period of taper, which leaves your body fresh and ready for competition, with lots of training banked up from which to draw.

Training sessions

Depending on which training cycle you are in, you will often cover varying sessions on endurance/stamina work and speed/power work. There are hundreds of different swim sets you could carry out through a certain training cycle.

Below are examples of what to include in those sessions, at what intensity, and how much rest should be given. These examples are to be used as a ‘main set’ for a single training session. A quality warm-up and ‘lead-in’ set should be completed first, followed by a recovery set and cool-down, depending in the length of the session, training cycle, etc.

1. Endurance

Any competitive swimmer must incorporate this type of training throughout their season or given cycle. This will build their physiological aerobic base from which to develop more specifically for their needs, whether it is simply fitness or distance based swims (400 metres or 1500 metres) or sprint-based swims (50 metres or 100 metres).

2. Basic endurance

This involves working at a heart rate level of 65 to 75% MHR for a period of 15 to 60 minutes. Rest within the sets should be between 10 to 30 seconds depending on the distance repeats you are swimming.

Example sessions:

- 20 x 100 metres, 10 to 15 seconds recovery, 60 to 75% MHR
- 5 x 400 metres, 20 to 25 seconds recovery, 60 to 75% MHR

3. Threshold endurance

This involves working at a heart rate level of 80 to 85% MHR, for a period of 15 to 45 minutes. Rest within the sets should be between 10 to 30 seconds depending on the distance repeats you are swimming.

Example session:

- 10 x 200 metres, 15 seconds recovery, 80 to 85% MHR

4. Overload endurance

Occasional endurance sets should involve this type of training, whereby you swim at a heart rate level of 85 to 90% MHR for a period of 15 to 30 minutes. Recovery within the set should be no longer than 30 seconds depending on the distance repeats you are swimming. The main aim of this type of training is to work for a solid length of time at a high intensity with little rest to ensure the working muscle groups achieve overload. As you know, without achieving overload, progression will not occur within a given time scale.

Example sessions:

- 5 x 200 metres, 15 seconds recovery, 85 to 90% MHR + 10 x 100 metres, 10 seconds recovery, 80 to 85% MHR
- 3 x 400 metres, 20 to 25 seconds recovery, 85 to 90% MHR + 4 x 300 metres, 15 to 20 seconds recovery, 85 to 90% MHR

5. Sprint

Sprint training adds the anaerobic fitness base to the aerobic base you have developed with your endurance training. It works on the two anaerobic energy systems: the Creatine phosphate energy system and the lactate energy system. Training involves short, fast repeats with good rest intervals to ensure you can overload both these energy systems. The additional benefit of sprint training is muscle adaptation to the speed type exercise, as well as the aerobic benefits trained earlier. Working the fast twitch muscle fibres will increase their number and size in a given muscle as well as the speed of excitation.

The following examples of training sets are to be used as a ‘main set’ as with the previous endurance examples.

Lactate tolerance

This involves working at a heart rate level of 90 to 95% MHR, with substantial rest periods within the given set. The aim is to work close to maximum speed and then to rest (for between 3 and 5 minutes) in order to give time for some lactate to be broken down and eliminated.

Example sessions:
- 6 x 50 metres, 4 min recovery, Maximum pace
- 4 x 100 metres, 5 min recovery, Maximum pace

Lactate production

The aim of this type of set is also to exercise at close to maximum but with less rest (between one and three minutes) in order for your body to experience exercising with lactate build-up in your system. This therefore involves working at a heart rate level of 90 to 95% MHR.

Example sessions:
- 10 x 50 metres, 1 min recovery, Maximum pace
- 6 x 100 metres, 2 min recovery, Maximum pace

Technique Drills

One final area of a training session is swimming 'drills'. The aim is to slow the stroke down and to concentrate on and practise the key areas of technique, whether it is the high area recovery on Freestyle, the symmetrical arm cycle of the butterfly, the timing of the kick and pull on breaststroke or the shoulder roll on the backstroke arm cycle. These can form part of the warm-up or lead-in set or even the recovery set.

More specific work can be done with the use of a float and a pull buoy. For example, kicking drills with or without flippers/with or without a float, speed or endurance kick sets depending on your current training cycle. Pulling sets can work very well on technique, endurance as well as power development in the arm cycle. Again, these sets could be used as part of the warm-up, lead-in set or recovery set.

Strength

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

Tapering for competition

A common practice used by swimmers and coaches is the well established technique of tapering, whereby the volume of training is reduced before competition. When planning a tapering program consider the following points:

- Reduce the training volume by 60 to 90%
- Undertake high intensity work – 90% VO_2 max
- Reduce frequency of training by no more than 20%
- Duration of 7 to 10 days – due to individual responses to tapering you will need to identify the optimal duration for the athlete

The training week

A whole host of different types of training sessions can fit into the week of the swimmer, giving the coach and physiologist ample opportunity for workouts of slightly different intensity. The structure of the week will vary according to the particular phase but it is important that all aspects are covered to different degrees, all year round.

Four major intensities can be established and these in turn may well be subdivided to give a greater range of options. In base endurance sessions, you work at very low intensities to enhance the oxidative capacity of the muscles and increase the ability to metabolise fats as an energy substrate. Aerobic maintenance sessions will form a large bulk of volume, where the intensity is a little harder to give a greater stimulus to the heart and lungs. Threshold work should give the optimal aerobic training effect, provided the intensity is right. If you are too fast, there is a greater contribution from anaerobic metabolism, and if you are too slow, you could be going faster. Speed endurance, or lactate production and lactate tolerance sessions are far more intense and so need to be done in interval workouts to keep sufficient volume.

Added to these conditioning sessions should be flexibility work, before and after pool sessions, and in sessions in their own right. Technique work is also vital in a sport where hundredths of a second really count. Work in the weight room can increase strength and power, a crucial factor in swimming success, but it is important to choose exercises that are actually going to contribute to an increase in swimming velocity. If they are not specific to your sport, then the value of time spent on such work is, at best, questionable.

Joe Dunbar

Module 2

Conditioning

Introduction

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 nine elements that comprise the definition of fitness and they are: Strength, Power, Agility, Balance, Flexibility, Local Muscle Endurance, Cardiovascular Endurance, Strength Endurance and Co-ordination.

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

Overview of the articles in this section

- Brad Walker explains the content, format and benefits of circuit training
- John Shepherd provides advice on how agility drills can be used to enhance an athlete's performance

- Walt Reynolds reviews the workouts that can boost fitness, speed, endurance and correct weaknesses

The articles in this section are applicable to most sports.

How to simultaneously improve mobility, strength and stamina

Circuit training routines are one of my favourite training sessions, whether for myself personally, or for clients. I use circuit training as part of injury rehabilitation programs, for conditioning elite level athletes, or to help my clients lose weight.

I was introduced to circuit training routines by an exceptional sports coach by the name of Col Stewart. Col is one of those rare coaches who can take just about any sport and devise a specific training program that always produces outstanding improvements for his athletes.

Col's circuit training routines are largely responsible for the success of many of his world champion athletes. Including his son, Miles Stewart (World Champion Triathlete), Mick Doohan (World 500cc Motorcycle Champion), and countless others from sports as diverse as roller-skating, squash, and cycling.

So what is circuit training?

Circuit training consists of a consecutive series of timed exercises performed one after the other with varying amounts of rest between each exercise.

For example, a simple circuit training routine might consist of push-ups, sit-ups, squats, chin-ups and lunges. The routine might be structured as follows, and could be continually repeated as many times as is necessary.

- Do as many push-ups as you can in 30 seconds, then rest for 30 seconds
- Do as many squats as you can in 30 seconds, then rest for 30 seconds
- Do as many sit-ups as you can in 30 seconds, then rest for 30 seconds
- Do as many lunges as you can in 30 seconds, then rest for 30 seconds
- Do as many chin-ups as you can in 30 seconds, then rest for 30 seconds

What makes circuit training so good?

The quick pace and constant changing nature of circuit training places a unique type of stress on the body, which differs from normal exercise activities like weight training and aerobics.

The demands of circuit training tend to prepare the body in a very even, all-round manner. I have found circuit training to be an exceptional form of exercise to aid in the prevention of injury. Circuit training is one of the best ways I have found to condition your entire body and mind.

There are many other reasons why circuit training is a fantastic form of exercise, and what most of these reasons come down to is flexibility. In other words, circuit training is totally customisable to your specific requirements.

- Circuit training can be totally personalised. Whether you are a beginner or an elite athlete you can modify your circuit training routine to give you the best possible results.
- A circuit training routine can be modified to give you exactly what you want. Whether you want an all-over body workout or you just want to work on a specific body area or you need to work on a particular aspect of your sport.
- You can change the focus of your circuit training routine to emphasise strength, endurance, agility, speed, skill development, weight loss, or any other aspect of your fitness that is important to you.
- Circuit training is time efficient. No wasted time in between sets. It is maximum results in minimum time.
- You can do circuit training just about anywhere. One of my favourite places for doing circuit training is at some of the parks and playground areas near where I live. Circuit training is a favourite form of exercise for the British Royal Marine Commandos because they tend to spend a lot of time on large ships. The confined spaces means that circuit training is sometimes the only form of exercise available to them.
- You do not need expensive equipment. You do not even need a gym membership. You can just as easily put together a great circuit training routine at home or in a park. By using your imagination you can devise all sorts of exercises using things like chairs and tables and even children's outdoor play equipment like swings and monkey bars.
- Another reason why I like circuit training so much is that it is great fun to do in pairs or groups. Half the group exercise while the other half rests and motivates the exercising members of the group.

The main types of circuit training

As mentioned before, circuit training can be totally customised, which means there is an unlimited number of different ways you can structure your circuit training routine. However, here are a few examples to give you some idea of the different types available.

Timed circuit

This type of circuit involves working to a set time period for both rest and exercise intervals. For example, a typical timed circuit might involve 30 seconds of exercise and 30 seconds of rest in between each exercise.

Competition circuit

This is similar to a timed circuit but you push yourself to see how many repetitions you can do in the set time period. For example, you may be able to complete 12 push-ups in 30 seconds. The idea is to keep the time period the same, but try to increase the number of repetitions you can do in the set time period.

Repetition circuit

This type of circuit is great if you are working with large groups of people who have different levels of fitness and ability. The idea is that the fittest group might do, say 20 repetitions of each exercise, the intermediate group might only do 15 repetitions, while the beginners might only do 10 repetitions of each exercise.

Sport specific or running circuit

This type of circuit is best done outside or in a large, open area. Choose exercises that are specific to your particular sport, or emphasise an aspect of your sport you would like to improve. Then instead of simply resting between exercises, run easy for 200 or 400 metres. You can even use sprints or fast 400 metre runs as part of your choice of exercises.

Some important precautions

Circuit training is a fantastic form of exercise, however, the most common problem I find is that people tend to get over excited, because of the timed nature of the exercises, and push themselves harder than they normally would. This tends to result in sore muscles and joints, and an increased likelihood of injury.

Two precautions you need to take into consideration

1. **Your level of fitness.** If you have never done any sort of circuit training before, even if you consider yourself quite fit, start off slowly. The nature of circuit training is quite different to any other form of exercise. It places different demand on the body and mind, and if you are not used to it, it will take a few sessions for your body to adapt to this new form of training. Be patient.

2. **Your warm-up and cool-down are crucial.** Do not ever start a circuit training routine without a thorough warm-up that includes dynamic stretching. As I mentioned before, circuit training is very different from other forms of exercise. Your body must be prepared for circuit training before you start your session.

Brad Walker

Sport specific drills for boosting agility

Muhammad Ali was the greatest. The champ had a superb athletic physique, awesome punching power and one of the fastest pairs of feet and hands ever to grace any athlete, let alone a boxer. He was so quick, he boasted, that he could flick off the light switch and then get into bed before the light went out! Maybe he was exaggerating his abilities here, but the champ was incredibly agile. So what can you do to develop equally ferocious agility?

In sport, agility is characterised by fast feet, body coordination during change of direction and sports skill performance, and reaction time/ability. It is an amalgam of balance, speed, strength, flexibility and coordination. Although a performer's agility relies heavily on the acquisition of optimum sports technique, it can also be enhanced by specific conditioning.

A variety of performance enhancing agility drills, systems and items of equipment are available to the sportsmen of today and their coaches. The 'science' of agility (and speed and power) training has made rapid strides recently, especially in terms of its accessibility to the mainstream sporting world.

Dissecting a sports skill

Essentially, agility training dissects a sports skill: a skill like the fast stepping ability required of a rugby player is broken down into its constituent parts, which are then specifically trained. It's all about patterning and conditioning a heightened physical, neural, sport specific response.

Let's consider in more detail the process involved in developing fast feet. One of the major tools available for this purpose is the floor based rope ladder. This piece of kit is a key element of the Sports, Agility and Quickness system; (SAQ International is the world's leading company for packaging and marketing sports specific training and has been used by England's Rugby World Cup winning squad).

A wide variety of running, hopping and jumping drills can be carried out in all directions, using the rungs of this ladder, which is laid flat on the ground. Such drills enhance foot speed and upper body agility, just like any other aspect of sports performance, by progressive overload. England rugby wing Ben Cohen has been specifically singled out as a player whose feet have been rendered especially fleet by means of extensive use of the rope ladder and other agility training methods.

Speed through a floor ladder can indicate much about a player's quickness [1]. A time of less than 2.8 seconds (male) and 3.4 seconds (female) for running the length of a 20 rung ladder, one foot in each rung at a time, is regarded as 'excellent' for college athletes.

Agility training also utilises numerous other drills and items of specialist kit; these include balance drills, slaloming in and out of cones and stepping over and around small hurdles. To make the transference of the agility skill even more sport specific, an actual sports skill can also be introduced. This could take the form of dribbling a football in and out of cones, or receiving a rugby pass while stepping through a foot ladder.

SAQ in female footballers

Obviously, companies like SAQ International claim their systems get results and improve players' agility. But is their confidence justified? Polman and associates looked at the effects of SAQ techniques on female footballers over a 12 week period [2]. The players were divided into three groups, two performing SAQ training, while the third carried on with their normal conditioning programs.

The results were as follows:

- All three interventions reduced the participants' body mass index (-3.7%) and fat percentage (-1.7%), and increased flexibility (+14.7%) and VO_2 max (+ 18.4%)
- However, the SAQ groups showed significantly greater benefits from their training program than the other group on a sprint to fatigue test, a 25m sprint, and left and right side agility tests

Working to improve the agility of a dynamic sports performer (like a footballer or rugby player) by means of SAQ and similar techniques seems highly appropriate, relevant and valuable. But will the same principles apply to endurance athletes? After all, quick as a flash agility is not a pre-requisite for triathlon or marathon running.

Alricsson and associates carried out a study to evaluate whether dance training had any effect on the joint mobility and muscle flexibility of the spine, hip and ankle and on the speed and agility of young cross country skiers [3]. Cross country skiing is a not a sport renowned for quick dynamic movement, but shaving seconds off on every turn and jump could add up to significant time savings. Dance training was selected for this task because of its potential contribution to agility and flexibility.

The study involved 20 elite cross country skiers, aged 12 to 15, with half of them (five girls and five boys) receiving weekly dance training and the rest serving as non dancing controls for a period of eight months. Joint mobility and muscle flexibility of the spine, hip and ankle were measured before the study period and at three and eight months. Two sport related functional tests – a slalom test and a hurdle test were carried out at the same times.

The researchers found that the dance group had increased their speed by a total of 0.3 seconds over the slalom test after eight months. They also improved their speed and agility on the hurdle test by 0.8 seconds after three months and by a further 0.6 seconds after eight months. Furthermore, they increased flexion and extension of the thoracic (upper) spine by 7.5° after three months and by a further 1.5° after eight months, while lateral flexion improved by 0.04mm and a further 0.03mm over the same periods. Meanwhile, the non dancing controls did not show any improvements in any of the studied variables.

Effects of dance training

Alricsson concluded: 'Dance training has a positive effect on speed and agility and on joint mobility and muscle flexibility in flexion-extension and lateral flexion of the spine in young cross-country skiers'. Had his subjects made use of more sport specific agility training, the chances are that their gains would have been even greater.

Marathon runners do not have to dart sideways, backwards and forwards with lightning speed over the course of their 26 mile effort, so could they have anything to gain from agility training? To answer this question, we need to consider the interplay between agility and power training.

Research indicates that, despite prolonged running training, runners' leg muscles may not actually be that efficient at returning energy to the running surface. In fact, at certain speeds these muscles may be working at only 50% efficiency because of the 'natural' energy return effectiveness of the foot arch and Achilles tendon [4].

It's a bit like having an engine turbocharger that works in reverse. Your Achilles and foot arch are the turbo: they cut in automatically when your foot strikes the ground, producing a burst of power but leave the running muscles (quads, hamstrings and calf muscles – the engine) working at less than their full potential. Unless you target these running muscles with specific power conditioning drills, your ability to drive up running speed can be compromised.

Such exercises as hopping on and off of a low box and spring jogging (virtually straight leg movements, where the performer propels himself forwards primarily by means of feet and ankles) not only develop 'harder', and therefore more effective, running muscles through their plyometric effect, but also improve agility.

Plyometric exercises enable muscles to generate huge amounts of force in a split second when a concentric (shortening) muscular contraction immediately follows an eccentric (lengthening) contraction of the same muscle. These agility and power moves can 'sharpen' foot/ground contact and result in a more economical and powerful running stride, regardless of running distance.

Backwards and sideways running can also 'pre-habilitate' against injury, providing a further reason why endurance runners (and those involved in running based sports) should perform agility training.

As mentioned above, conditioning exercises, such as a plyometric drills can develop both agility and power. However, these drills may not exactly match what is required in a playing situation. To ensure they do, it is essential for coaches to analyse in real detail the agility and movement patterns required for their sport and to use this information to construct the most relevant conditioning program. In this respect foot positioning can be crucial.

Kovacs and associates looked at the relevance of foot positioning, particularly foot landing positions, in athletes performing plyometric depth jumps drills involving stepping off a box then immediately springing upwards, sideways or forwards [5]. Specifically, the researchers were interested in comparing the force generated by flat footed and forefoot ground contacts.

Ten male university students performed two types of depth jump from a 0.4m high box placed 1m from the centre of a force plate. They were instructed to land either on the balls of their feet, without the heels touching the ground, or on their heels. The researchers discovered that the two different jumping styles generated force in very different ways. Using specific measuring equipment, Kovacs' team demonstrated that a forefoot landing depth jump produced significantly more power at impact and at the transition into the jump than a flat footed landing depth jump.

Depth jumps and power

Kovacs' findings have crucial implications for optimum agility and power conditioning. Even though a flat footed landing depth jump will develop power, this may not channel optimally into enhancing the agility and power of a player in a specific sport. For example, a sprinter would probably benefit more from forefoot landing jumps, as the sprint action is performed from a similar foot strike position, whereas a basketball or volleyball player is likely to develop greater vertical spring, a key requirement of the games, by using flat footed landings. Muscle firing patterns are very specific, and conditioning drills must mirror sports skills for optimum results.

Finally here's an example of an even more specific agility/power conditioning drill, designed for a tennis player. The player should perform a depth jump with a forefoot – but non-aligned – landing position, which will enable him or her to rotate and sprint, in three to five strides, to a designated target to the left or right.

This drill mimics and conditions the typical agility (power and speed) required in a game situation, *eg* to reach a drop shot. And it can be made even more specific if the player holds a racket and 'ghosts' a shot on reaching the designated target.

In summary, if you or those you coach want to become faster, more elusive, more efficient and more dynamic in their movements, it is advisable to incorporate specific drills into regular training routines.

John Shepherd

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Run-Play workouts

How can you improve your fitness, including your speed, speed endurance, leg power, and work capacity, while at the same time having fun and introducing variety into your regular routine? The answer is to rely on 'run-play' workouts. Run-play is a variation of conventional Fartlek or 'speed-play' training and involves a mixture of running, bounding, and sprinting exercises that are combined with mobility and agility drills to form a sequenced training session of high energy activity.

Run-play workouts can be altered to suit the needs of different athletes, and specific weaknesses in an athlete's fitness (in speed, stamina, or leg power, for example) can be corrected by accenting various portions of the overall run-play format. Individuals who need more speed can emphasise the speed training units, while those who lack stamina can focus on speed endurance, and so on.

Run-play workouts can be especially helpful during the general preparation or base building phases of training. However, periodic use of the run-play format can give you much needed variation in your training during the pre-competitive and competitive phases of training. All run-play activities, including warm ups, running, sprinting, bounding, and various drills, should be performed on a soft, resilient surface away from the track and roads, so the best site for run-play training is an outdoor trail, a park, or a level, grassy field.

Run-play training can be carried out by individuals or groups; with groups, run-play can be incorporated into a game of 'follow the leader' which increases camaraderie and helps build team unity (especially when used with young athletes). Coaches can easily add new activities to the run-play format to keep the programme interesting and fun. Run-play sessions are typically scheduled near the end of a training week (on Saturday, for example) and are followed by a day of rest or light training to allow for complete recovery and the re-stocking of energy stores.

The actual number of exercises, drills, and activities in run-play training is virtually limitless, but the basic pattern of training units (for mobility, power, speed, and endurance) is organised in a way that emphasises the specific characteristics of an athlete's particular event.

For example, in the case of runners:

- a sprinter is looking for greater leg power, acceleration, and maximal speed
- a middle distance competitor is primarily trying to improve basic speed and speed endurance
- a distance runner is hoping for better speed endurance and aerobic endurance

The actual composition of a speed play workout is different for each type of athlete.

Here are the basic training units, which are the 'building blocks' of run-play workouts.

The warm up

The warm up starts slowly and progresses in speed and intensity over a 20 to 25 minute period. Begin your warm up with a combination of walking, marching (walking with an exaggerated knee lift), and slow jogging for a total of about 150 to 200 metres. Then progress into 50 to 100 metre segments of trotting (fast jogging), skipping, 'grapevine stepping', backward jogging, side shuffles, and small jump bounding (from foot to foot) over the course of about 800 to 1000 metres. Between each exercise, jog slowly for a little while, and try to perform the activities in multiple directions (backwards, and sideways right and left, in addition to straight ahead) in order to add variety, fun, and increased difficulty to the warm up.

This initial portion of the warm up serves to raise your body temperature, increasing the blood flow to your working muscles. It engages your nervous system, muscles, and joints in low level agility activities that prepare you well for your actual training.

Your warm up period continues with dynamic mobility exercises, which increase the range of motion in the major joints of your body. Arm swings, neck movements, trunk and shoulder motions, hip circles and twists, leg swings, and ankle bounces should be performed for about 10 to 15 repetitions each, following one after the other with minimal interruption.

The warm up concludes with running activities that are specific to your preferred sport and prepare you completely for the training activities, which form the main portion of your workout.

Warm up for sprinters, basketball players: Complete two repetitions ('reps') of 60 to 80 metre strides at about 75% of your maximum speed, with a 60 to 80 metre, walk back recovery. To work out what is 75% of your maximum speed, put your various running paces on a scale of one to 10, with 10 being your absolute maximum speed. Then try to run the repetitions at a speed which would correspond with about 7.5 on this scale. Follow the two strides with two 40 to 50 metre accelerations where you increase your speed from 50% to 90% of maximum over the course of 40 to 50 metres. Use a slow walk back to the starting point, while keeping your legs loose and relaxed ('shake them out' if necessary) for recovery.

Warm up for middle distance runners and soccer players: Carry out two repetitions of 120 to 150 metre light runs at about 65% of maximum speed, with a 120 to 150 metre jog back recovery. Follow the light runs with two 80 to 100 metre strides at 75% of maximum speed. Each stride is followed by a walk back recovery.

Warm up for distance runners: Run two repetitions of 150 to 200 metre light runs at 60% of maximum speed, with a 150 to 200 metre, jog back recovery. These are followed by four 100 to 120 metre strides at 75% of maximum speed. Follow each stride with a walk back recovery.

After completing the warm up, move directly into the training exercises described below. Follow the order outlined for your specific event.

Leg power improvement

Leg power exercises include horizontal bounding and hopping. Bounding and hopping are basic forms of plyometric training, which can enhance your leg power and running speed by increasing the 'reactive' capabilities of your legs. As your legs become more 'spring like', you will get more energy out of each stride, and your stride lengths will naturally increase.

The bounding sequences in your run play workout can include the following:

Sprint events, basketball: Use four to six sets of 10 bounds, alternating from your left foot to your right, back to the left, and so on. Each foot contact with the ground counts as one bound (each foot strikes the ground five times to make 10 bounds). A walk back to your starting line follows each set of 10 bounds. After the bounds have been completed, perform four to six sets of eight to 10 hops on your left leg, again with walk back recoveries. This pattern is then repeated with your right leg. Try to make the bounds as long and as fast as possible.

Middle distance events, soccer: Perform three to five sets of the bounds and hops as described above, with walk back recoveries between sets.

Distance events: Complete two to four sets of the bounds and hops described above, with walk back recoveries. Do not worry too much about the distance covered with each bound or hop; instead just focus on keeping up a good rate of movement.

Speed development

Run-play training helps develop foot speed by emphasising exercises, which focus on improving sprint form while running at less than maximal velocities. The increased speed, which is developed then, provides the foundation for more specific speed training, which is carried out during the pre-competitive and competitive phases of the training year.

Run-play speed training is applied to the sprint and middle distance events as follows:

Sprint events: Complete four to six repetitions of form accelerations. These accelerations begin slowly with a jog and build up smoothly and quickly to 90% of maximum speed over a 30 to 50 metre distance. Then maintain this speed for an additional 20 to 30 metres. The focus during these form accelerations should be on a powerful knee and arm drive, an upright posture with a stable trunk, and strong but quick ground contacts with each foot strike. Include a slow walk back to your starting point with 'leg shaking' if necessary to keep your leg muscles loose during each recovery period. Three to four repetitions of form sprints follow form accelerations.

These sprints are carried out at an intensity of 85 to 90% of maximum speed over a 60 to 80 metre distance. Each rep is followed by slow walking back to the start line and leg shaking for recovery.

Form accelerations and form sprints teach you the 'feeling' of acceleration and fast running. High speed running is a skill that must be practised and refined through many repetitions of sprinting exercises. Form accelerations and sprints help develop this 'speed skill' through the practice of sprinting mechanics and the controlled build up and maintenance of running speed.

Middle distance events: Conduct four to six repetitions of form sprints as outlined above, over a distance of 120 to 200 metres at 85 to 90% of maximum speed. For recovery, just walk slowly back to your starting point, keeping your leg muscles as loose as possible.

Speed endurance development

The ability to maintain submaximal, but high quality, running speeds over distances of 150 metres or more requires the development of speed endurance. Speed endurance training improves your ability to tolerate increased amounts of lactic acid in your system and lessens your feelings of fatigue as you run at faster speeds. Speed endurance development is most important for runners who compete in events of 400 metres and longer. They can also be used by sprinters as a form of base training.

The speed endurance component of run-play training includes the following:

Sprint events: Carry out four to six repetitions of 150 to 300 metre rhythm runs at about 75 to 80% of maximum speed. The focus during these runs is on smooth running form and a quick, consistent rhythm (leg turnover). Somewhat paradoxically, the longer distances (250 to 300 metres) are used in the early weeks of training, and the rhythm runs get progressively shorter (150 to 200 metres) but faster as the season progresses. Each rep is followed by a walk back recovery of the same distance.

Middle distance events: Complete three to six repetitions of 300 metre rhythm runs at 800 metre race pace if you compete at 800 metres or three to six repetitions of 500 metre rhythm runs at 1500 metre race pace if you are primarily a 1500 metre competitor. If you compete at both distances, do half of your rhythm runs at 800-metre speed and half at 1500 metre tempo. These runs are carried out in the manner described above for sprint competitors, but are followed by slow, jog back recoveries instead of walks.

Distance events: Conduct four to eight sets of 300 to 500 metre rhythm runs at about current 5k race speed. Perform the runs as described above, along with slow jog back recoveries.

General endurance upgrades

General endurance or stamina is developed by completing bouts of continuous activity at moderate intensifies, performed for longer than three minutes. The general endurance component of run-play training includes the following:

Middle distance events: Carry out a cool run of 2000 to 3000 metres at around 70 to 75% of maximal heart rate. A cool run serves as a wrap up to the main training portion of a run-play workout and should be performed at a relaxed and easy conversational pace.

Distance events: Try a cool run of 3000 to 5000 metres at about 70 to 75% of maximal heart rate. Do not try to run too fast. The pace should feel fairly easy and you should feel very relaxed.

Run-play cool down

For all athletes, the cool down portion of a run-play workout involves walking and jogging for a distance of 500 to 800 metres, followed by a short period of static stretching which especially focuses on the calves, hamstrings, quads, and hip and buttock muscles. This concluding segment of a run-play session should not be neglected, because it allows your body to gradually return to a state of rest.

Run-play glossary

Marches: Walking with an exaggerated knee lift, bringing the thigh of the 'swing' leg parallel to the ground as it moves forward and upward.

Grapevine Stepping: Jogging sideways while alternating a cross in front and cross behind step. For example, to grapevine step, you would move your right leg to the left, crossing over the front of your left leg, then move your left leg sideways so it is again 'leading' the right leg, and then cross your right leg behind your left leg, continuing this pattern for the specified distance and then changing so that the left leg crosses in front of and behind the right leg.

Strides: Repetitions performed at approximately 75% of maximum speed. Actual distances vary depending on the training objectives but are typically 60 to 150 metres in length.

Accelerations: Speed oriented runs that begin with a jog at approximately 50% of maximum speed and accelerate smoothly to 90% of maximum over a short distance – 20 to 60 metres.

Light runs: Runs performed at approximately 60% of maximum speed over distances of 120 to 200 metres.

Horizontal bounding: Jumping from one foot to the other repeatedly while moving forward over the ground. When performed correctly, bounding resembles a very long running stride, with an exaggerated knee lift.

Hopping: Jumping on one foot repeatedly while moving forward. Also known as one legged running.

Form accelerations: Accelerations, which emphasise a powerful knee and arm drive, an upright and stable trunk position and a strong push off on each foot strike. To complete a form acceleration, you build up to approximately 90% of maximum speed over the first 40 t0 50 metres and then maintain this speed for about 20 to 30 additional metres.

Form sprints: Runs performed at 85 to 90% of maximum speed over distances ranging from 60 to 200 metres, depending on the event. Carried out with an emphasis on proper sprint mechanics.

Rhythm runs: Runs completed at about race pace for 800 metre and 1500 metre competitors (if you run both races, half of your rhythm runs should be at each pace) or 5k race tempo for distance runners, over distances of 150 to 500 metres. The focus is on correct running form and the establishment of an appropriate 'rhythm' (leg turnover) for racing.

Cool runs: Continuous efforts of about 2000 to 5000 metres at a moderate, conversational intensity (talking pace) of about 70 to 75% of maximal heart rate.

Walk or jog back recoveries: Recovery periods between runs, bounds, or hops, which involve walking or jogging the distance covered during a repetition.

Walt Reynolds

Module 3

Mobility

Introduction

Mobility is the ability to perform a joint action through a range of movement. In any movement there are two groups of muscles at work: the protagonistic muscles which cause the movement to take place and opposing the movement and determining the amount of mobility are the antagonistic muscles.

If athletes are to learn and utilise effectively the techniques associated with their events and are to avoid injury successfully, they require a good level of mobility. An athlete will find it difficult, if not impossible, to learn a new technique if their mobility is poor. The coach might mistakenly put the lack of progress down to a lack of strength or poor coordination, when in fact the athlete is not capable of assuming a required position due to a lack of mobility. A good level of mobility is also essential for the development of specific conditioning (*ie* the application of strength or speed in a particular event).

In throwing events the athlete needs to apply force to the implement over the longest possible range. A lack of mobility will reduce the effective range over which force can be applied. Even in endurance events, where the actual ranges of movement may be limited, good mobility is essential as it allows free, efficient movement. The athlete will be able to develop a good, effective technique which in turn will reduce energy demands placed on the athlete.

There is no doubt that time spent on warming up and cooling down will improve an athlete's level of performance and accelerate the recovery process needed before training or competing again. As a result the coach must encourage the athlete to regard the warm up and cool down as an essential part of both the training session and competition itself.

Overview of the articles in this section

- Chris Mallac provides a Readers Digest version of the background to the theory of stretching
- Raphael Brandon explores the benefits of flexibility training on athletic performance.
- John Shepard explains the need for a warm up and provides examples of appropriate exercises

The articles in this section can be applied to all sports.

A physiotherapist's view on flexibility

Most coaches, athletes and sports medicine personnel use stretching methods as part of the training routine for athletes. Many would agree that it forms an integral part of training and preparation. However, most of the theoretical and practical factors in stretching are often incorrectly applied. The purpose of this article is primarily to provide an overview on the theoretical basis of stretching routines.

What is flexibility?

De Vries defines it as the range of motion available in a joint, such as the hip, or series of joints such as the spine. This encompassing definition takes into account a number of important aspects about flexibility. That is, it deals with a joint or series of joints used to produce a particular movement, and it considers that flexibility is both static and dynamic in nature.

It is important to highlight some points regarding flexibility. First, flexibility is joint specific. That is, you cannot say someone is flexible just because they can touch their toes. The same person may not even be able to reach around and scratch the small of his/her back because their shoulder has poor flexibility. Second, flexibility is sport specific. You would not expect a front row rugby forward to have the same flexibility as an Olympic gymnast, because it is not required for his sport. In fact, in a contact sport like rugby, being that flexible would be detrimental to his body.

Components of flexibility

Flexibility has two important components: static and dynamic flexibility.

1. Static flexibility describes range of motion without a consideration for speed of movement. This is the maximum range a muscle can achieve with an external force such as gravity or manual assistance. For example, holding a hamstring stretch at an end-of-range position
2. Dynamic flexibility describes the use of the desired range of motion at a desired velocity (usually quickly). Dynamic flexibility is the range athletes

can produce themselves. For example, a javelin thrower or baseball pitcher needs a lot of shoulder rotational flexibility, but they also need to be able to produce it at rapid speeds of movement

Here are some useful points:

- Good static flexibility is a necessary pre-requisite for good dynamic flexibility; however, having good static flexibility does not in itself ensure good dynamic flexibility
- Dynamic flexibility is vitally important in those high velocity movement sports such as sprinting, kicking and gymnastics
- Dynamic flexibility is limited by the ability of the tissues to lengthen quickly, and the inhibition of what is called the 'stretch reflex', which if present would act to limit the range of motion (more about this later)

Why is flexibility important?

Good flexibility allows the joints to improve their range of motion. For example, flexibility in the shoulder musculature allows a swimmer to 'glide' the arm through the water using shoulder elevation. This allows the joints to easily accommodate the desired joint angles without undue stress on the tissues around them. It therefore is essential for injury prevention.

Stretching also forms an integral part of rehabilitation programmes following injury. For example, it is accepted that a muscle tear will heal with scar tissue. This scar tissue tends to be functionally shorter and have more resistance to stretch than normal healthy muscle tissue. Therefore stretching is used at an appropriate time in the healing process to assist in lengthening this contracted scar tissue.

Good flexibility improves posture and ergonomics. Our bodies have a tendency to allow certain muscles to tighten up which will affect our posture. Vladimir Janda, a Czech rehabilitation specialist, describes a group of muscles in the body that universally show a tendency towards tightness and also being overactive in movements. Some of these include the hamstrings, rectus femoris, TFI, piriformis, adductors, gastrocnemius and quadratus lumborum. These muscles are often implicated in postural syndromes causing musculoskeletal pain.

Flexibility, because it allows good range of motion, may improve motor performance and skill execution. Think of a sprinter who needs flexibility in the hip flexors to allow good hip extension at toe off, and good hip extensor flexibility to allow necessary knee drive in the leg recovery phase of sprinting. Skill execution and reduced risk of injury will be greatly enhanced if the body has the flexibility necessary for that particular sport.

There is also an argument that stretching may reduce post exercise muscle soreness, or delayed onset of muscle soreness (DOMS), by reducing muscle spasm associated with exercise.

Relative flexibility

Shirley Sahrmann, an American physiotherapist, uses the term 'relative flexibility' to describe how the body achieves a particular movement using the relative flexibility available at a series of joints. She believes that in order for the body to achieve a particular range of motion, it will move through the point of least resistance, or area of greatest relative flexibility.

A good example is to think of a rower at the bottom of the catch position. In this position the rower must have his hands (and the oar) past his feet in order to generate the drive necessary to transfer force from his body to the oar. If for some reason the rower has excessively tight hips and can't bend up (or flex) the hips (usually due to gluteal tightness), his body will find somewhere else to move to compensate for that lack of hip flexibility. More often than not, this rower will flex the lumbar and thoracic spines to make up for the lack of hip flexion. That is, the back has more 'relative flexibility', and therefore contributes to the overall range of motion. In this case however, the back will exhibit movement that is more than ideal, possibly leading to lumbar and thoracic dysfunction and pain.

The concept of relative flexibility is vital when understanding movement dysfunction in athletes. It is imperative that joint movements are not looked at in isolation, for other more distant joints will influence that movement. Try this simple test to highlight this point. Sit on a chair with your upper back slumped (that is, assume a poor posture). Now, maintaining this position, try to elevate both arms above your head. Now straighten yourself up (assume a good posture) and try it again. Unless you have gross shoulder dysfunction, you will be able to elevate more with a straight back than a curved one. By assuming a slumped position, you prevent the upper back (thoracic spine) from extending. This extension of the upper back is necessary for full range elevation. Without extension, it is difficult for the shoulder to fully elevate. If you do this for long enough (months to years) eventually the lack of movement will attempt to be taken up elsewhere (such as the lower back, or the shoulder itself). This may eventually lead to breakdown of these joints due to the excessive movement they may eventually demonstrate.

What factors limit flexibility?

Flexibility can be limited by what are called 'active' or 'contractile' and 'passive' or 'non-contractile' restraints.

Muscle contraction is one of these 'active/contractile' restraints. Flexibility can be limited by the voluntary and reflex control that a muscle exhibits while undergoing a stretch, in particular a rapid stretch that activates the 'stretch reflex'. As a muscle is rapidly stretched, a receptor known as a 'spindle' causes the muscle to reflexively contract to prevent any further stretch. If left unchecked, the stretch reflex would work to prevent elongation while the muscle was being stretched. A benefit of ballistic or fast stretching is that the nervous system learns to accommodate by delaying the stretch reflex until closer to end of range of movement.

Furthermore, a resting muscle does not always mean that it is 'resting'. Muscles usually exist with a certain degree of muscle 'tone'. An increase in tone will increase the inherent stiffness in muscles. If you are scientifically minded, this describes the way actin and myosin remains bound and thus resists passive stretching of the muscle. The actin and myosin stay bound because of a constant low-level discharge in the nerves supplying that muscle. With actin and myosin unbound, a muscle should in theory be able to stretch to 150 per cent of its original length (in theory of course).

'Passive/non-contractile' restraints in the form of connective tissues will also limit flexibility. The passive restraints include the connective tissues within and around muscle tissue (epimysium, perimysium and endomysium), tendons and fascial sheaths (deep and superficial fascia). The important microscopic structure to consider in passive tissues is collagen. The way collagen behaves with stretching will be discussed shortly.

Other passive restraints include the alignment of joint surfaces. An example of this is the olecranon of the elbow in the olecranon fossa that will limit full extension (straightening) of the elbow. Other joint constraints include capsules and ligaments. The joint capsule/ligament complex of the hip joint is important in limiting rotation of the hip.

The nerves passing through the limbs can also limit flexibility. As a limb is taken through a full movement, the ropey nerve tracts also become elongated and become compressed. The nerve endings and receptors in the nerves trigger a reflex response that causes the muscle to increase its resistance to stretch.

In addition to the points mentioned above, there are a number of other factors that influence flexibility.

- An older muscle has more inherent stiffness due to the morphological changes in the muscle and collagen in the connective tissues
- A muscle that has been immobilised with a cast will demonstrate increase in stiffness over time (longer than four weeks)
- Excessive training causes more cross linking to occur between collagen fibres and therefore increase stiffness
- Excessive repeated muscle contractions cause high volumes of neural discharge. A muscle can remain in a state of high resting tone following training sessions
- Increase in temperature causes a decrease in muscle stiffness. This can be environmental temperature or temperature increases induced by friction of muscle contraction. We therefore tend to be less stiff around 2.00 in the afternoon

- Finally, an increase in intramuscular fluid (fluid in the muscle cell) can increase stiffness due to a splinting effect. This is the proposed reason why use of Creatine monohydrate tends to make muscles feel stiffer

More about collagen

I mentioned earlier that the connective tissues in and around muscle are considered to be 'passive' or 'non-contractile'. The principal structure in these tissues we need to consider is collagen. A key term used in physics and biomechanics to describe the way collagen behaves is 'viscoelasticity'.

Viscoelastic tissues are made up of viscous and elastic properties. A viscous tissue will deform and stay deformed permanently – if you pull on a piece of play dough, for instance, it will keep that shape. An elastic tissue will return to its original length when the force is removed. For example, pulling on a rubber band and letting go – the band snaps back to its original length. Viscoelasticity describes a property of tissues (collagen being one of those tissues) whereby deformation/lengthening of a tissue is sustained and the recovery is slow and imperfect when the deforming force has been removed. That is, it will stretch, then stay stretched for a while before slowly returning to its original length.

Viscociasticity tells us a number of practical things about stretching the connective tissues in muscle:

1. Studies on the cyclic loading of tissues suggest that most deformation occurs in the first stretch, and after four stretches there is little change in ultimate length. Therefore there is no extra benefit from stretching a muscle 10 times in one session
2. It takes 12-18 seconds to reach stress relaxation, so there is no need to hold a stretch for longer than 20 seconds
3. Greater peak tensions and more energy are absorbed the faster the rate of stretch. This means that a tissue will generate greater tension if the rate of stretch is faster and therefore not achieve the same length as a tissue undergoing a slow stretch. That is, do passive stretches SLOWLY
4. Once elongated, length changes are not rapidly reversible due to the viscous nature of the tissue. However, deformations are not permanent because the elastic properties will eventually bring the tissue back to its original length. Lasting changes come from adaptive remodelling of the connective tissues, not mechanical deformation. One study in South Africa showed that stretching every four hours was the most effective way to achieve elongation in a muscle. This may suggest that the temporary change in length following a stretch may start to regress after four hours (Grace Hughes, unpublished study)

How stretching happens

A number of physical properties of viscoelastic tissues help describe how these tissues elongate with stretching. These properties are creep, load relaxation and hysteresis.

Creep describes the ability of a tissue to elongate over time when a constant load is applied to it. For example, if we applied 10 kg of force to our leg in order to stretch our hamstring, we might initially get our leg to 90 degrees before our tissues prevented further movement. If we sustained that load, we would find that our leg would gradually 'creep' a few degrees over a period of time.

Load relaxation describes how less force is required to maintain a tissue at a set length over time. Using the above example again, if we applied 10 kg of force to get our leg to 90 degrees, we would find that less force would be needed (9,8,7 kg etc…) to keep it at 90 degrees.

Hysteresis describes the amount of lengthening a tissue will maintain after a cycle of stretching (deformation) and then relaxation. Again, let's assume that if we gained an extra 10 degrees of range in hamstrings after the stretches described above, we would maintain that range for some time after the load was removed.

Neuromuscular considerations

Certain neuromuscular mechanisms acting on muscles influence 'tension' and have important implications for the value of stretching. These mechanisms include the stretch reflex, autogenic inhibition and reciprocal inhibition.

1. The stretch reflex is governed by a long thin receptor in muscles called a 'muscle spindle'. The spindle's role is to let our feedback systems know about muscle length and the rate of muscle lengthening. When a muscle is rapidly stretched, the spindle (via a loop of nerves) triggers a reflex contraction of the muscle undergoing stretch. A high-speed stretch will therefore trigger the spindle and a reflex contraction of the muscle will limit its ability to stretch
2. The spindle is also responsible for the phenomenon known as reciprocal inhibition. What happens here is that if a muscle contracts, the opposite or antagonistic muscle will relax to allow the movement to occur without resistance. For example, if the quadriceps are contracted, the hamstrings should relax to allow the knee to straighten
3. The Golgi Tendon Organ (GTO) is the important receptor to consider in 'autogenic inhibition'. The role of the GTO is to provide information on tension increases in muscles. This tension can come from contraction or stretch. The GTO connects with a small nerve cell in the spinal cord that inhibits or relaxes the muscle where the GTO is found. The GTO will trigger if a stretch is sustained (for longer than six seconds) or if the muscle contracts forcefully

The way these mechanisms are utilised will discussed below under the heading of Proprioceptive Neuromuscular Facilitation (PNF) type stretching.

The theory behind different stretching types

Static

Held static stretches are done so that the joints are placed in the outer limits of the available range and then subjected to a continuous passive stretch (gravity, weights, manual). One obvious benefit is that the chance of injury is minimal. This type of stretching is ideal to stretch the connective tissue/non-contractile elements since it makes use of the viscoelastic properties to cause elongation of the tissue. Furthermore, it makes use of autogenic inhibition to trigger a relaxation in the muscle (remember the six-second rule).

Dynamic

1. **Dynamic Range of Motion:** this describes a type of stretch whereby a muscle is taken through a full, slow and large amplitude movement. The opposing muscles are used to produce the force in this type of stretching. This type of stretching is done under control and is not jerky in nature
2. **Ballistic:** the type that is done fast and rapidly and through large ranges of motion. An example is leg swings to stretch the hamstrings. The benefit of this type of stretching is that it is sport specific to ballistic sports and it allows integration of the 'stretch reflex' if done quite often over a period of time. As the neuromuscular system adapts to this stretching, the stretch reflex will minimise its contribution to limiting muscle range
3. **Bouncing:** similar to ballistic, but it is performed in small oscillations at the end of range. The dangers of (2) and (3) are that they can lead to significant muscle soreness caused by the rapid lengthening of the muscle. This in itself initiates the stretch reflex and increases muscle tension. Furthermore, it fails to provide adequate time for the tissues to adapt to the stretch

PNF (Proprioceptive Neuromuscular Facilitation)

PNF uses the concept that muscle relaxation is fundamental to elongation of muscle tissue. In theory, it is performed in a way that used the proprioceptive abilities of the GTO and muscle spindle to relax or inhibit the muscle in order to gain a more effective stretch. It does so using autogenic inhibition and reciprocal inhibition.

PNF stretching exists in a number of different forms, but the only ones discussed here will be the contract relax (CR), hold-relax (HR) and contract relax and antagonist contraction (CRAC) methods.

a) Contract Relax (CR)
The muscle to be stretched is passively taken to end of range. Maximum contraction of the muscle to be stretched is performed against resistance (usually another person). With this form of contraction, the muscle is allowed to shorten during an isotonic contraction. This is continued for at least six seconds (which allows autogenic inhibition to occur). The muscle is then relaxed and taken to a new range and held for about 20 seconds. This can be repeated three to four times.

b) Hold Relax (HR)
Very similar to contract relax as above, but the contraction type is static/isometric. The muscle to be stretched is passively taken to end of range. Maximum contraction of the muscle to be stretched is performed against resistance (usually another person). With this form of contraction, the muscle does not shorten during its isometric contraction. This is continued for at least six seconds (allowing autogenic inhibition to occur). The muscle is then relaxed and taken to a new range and held for about 20 seconds. This can be repeated three to four times.

c) Contract Relax Antagonist Contraction (CRAC)
The first part of this stretch is similar to the CR method above; however, when the muscle to be stretched is relaxed after its six second contraction, the opposite or antagonist muscle is contracted for at least six seconds (allowing reciprocal inhibition to occur). The antagonist is then relaxed and the stretched muscle is taken to a new range.

Final thought

I have attempted to give a Readers Digest version of the background to the theory of stretching. Some of the theory is may be difficult to grasp, and may challenge your existing preconceived ideas of stretching.

Chris Mallac

For further reading

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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 sometime 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 result 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 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 or stretching habits and injury. On the other hand, one study of sprinters found that 4° 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 90º 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 (see 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: pp89-97) 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?

Raphael Brandon

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Ring out the old, ring in the new

It is a common human failing to look very hard, maybe too hard, at something and still fail to see what is staring you in the face. This may explain why coaches and athletes have continued to keep faith with the old style warm up despite mounting evidence that it does not do what it says on the tin. It is a given that we need to warm up before we sprint, hit a tennis ball or attempt a clean and jerk. The process prepares us mentally and physically for the task ahead. Traditionally, athletes from most sports have been used to raising their body temperature with five to 15 minutes of gentle cardiovascular (CV) work and then stretching off. As a long jump athlete, I can remember jogging a couple of laps to get really warm, then sitting and chatting for the next half an hour while supposedly stretching. By the time the session started, I would often be cold both physically and mentally. My body would have switched off and I would be far from optimally prepared for the dynamic activity to follow; in fact I would literally have to warm up all over again.

Stretching was a major component of the 'old' warm up, with coaches constantly reminding me that my range of movement had to be improved. But, with hindsight, the impact on my long jump performance of being able to do the ‘box splits’ or clutch one hand to the other behind my back seems negligible.

The 'new' theory about warm ups is that we should replace the old generalist approach with a much more dynamic, focused routine, specifically tailored to our chosen sport. The various drills we employ need to warm up our muscles specifically for the movements that will be required of them in the activity to follow. In this way specific neuromuscular patterning will be switched on and specific, functional range of movement developed.

It seems obvious, yet for some this is an almost revelatory concept. Former national track and field coach Tom McNab spoke at a recent meeting of the challenge that will need to be faced by coaches up and down the country, many of whom will have to turn their old ideas on their heads. Athletes, too, will need convincing to throw out the old concepts about warm ups and usher in the new.

But, in fact, the dynamic, focused warm up is not as new a concept as it appears. Athletes from the former Soviet Bloc were using these types of warm ups as far back as the 1970s – decades before they came to mainstream attention in the West. I remember attending a training course with former long jump world record holder and (at the time) head Soviet coach Igor Ter-Ovanesian in the early 80s, and being put through a short, sharp warm up, comprising star jumps and various agility moves. On receiving the instruction to warm up, all athletes attending the course had begun by plodding round the track, only to be called back by an exasperated Ter-Ovanesian and instructed in the 'new way'. Yet so entrenched were our ideas – and those of our coaches – on warming up that we failed to take this lesson to heart.

How, then, should we warm up? The following guidance will work for runners and players of running based sport, who need to be flexible enough to run efficiently in terms of power, relaxation and injury avoidance and (in running based sports) to make quick changes of direction. For such athletes, specific range of movement will be required in the shoulders, lower back, hips, hamstrings, quads, calf muscles and Achilles tendons. But preparing these areas for dynamic activity does not require lengthy periods of passive stretching.

First, raise your body temperature with five to 10 minutes of gentle CV work. Slow paced running is, after all, a very specific way to warm up your muscles for faster paced efforts, and there is still a need to prepare the CV system for more strenuous exertions. It is possible to incorporate many of the moves described below into a type of seamless warm up, *ie* by interspersing them with periods of jogging. But it is probably best to move gradually towards this goal over time – especially if you have always used the traditional, more staid, warm up approach.

You can increase the speed component of many of the drills as you become more proficient at performing them. This will 'fire up' your nervous system and increase the strength of your muscles for handling more dynamic contractions.

Performing these drills can also reduce the risk of common running injuries, such as shin splints, and can 'protect' the knee and ankle joints. Always think about being 'light' on your feet. Aim to perform each of the exercises below over 10 to 15 metres, with a walk back or jogging recovery. It should be enough to perform three to four repetitions of each.

- **Lunge walk –** for loosening up the hips, improving leg drive and strengthening the butt and hamstrings. Assume a lunge position and step forwards into another lunge. Keep your chest up, look straight ahead and co-ordinate your arms with your legs;
- **High knee lift –** for hip flexor and ankle strength. Extend up onto the toes and lift each thigh to a position parallel with the ground as you move forwards;
- **Elbow to inside of ankle lunge –** for hip flexibility, hamstring strength and stretching out the lower back. Similar to the lunge walk, but extend your trunk forwards over your front leg. If your right leg was in front of you, you would take the right elbow down toward the inside of the right ankle. Watch your balance!
- **Calf walk –** for lower limb strength and Achilles flexibility. Extending the ankle on each step will warm up the calf muscles and Achilles tendons;
- **Sideways and backwards skipping/running –** for lower limb strength, agility and flexibility. Other useful warm up exercises include:
- **Simulated running arm action, standing or seated.** The seated version is also great for specific core stability, as you have to work hard to maintain stability on the ground. Perform for 15 to 60 seconds, altering your speed of movement;
- **Leg drives.** Lean forwards against a wall, with your hands out at shoulder level and your feet shoulder width apart and approximately a metre from the wall. Look straight ahead and keep your body straight. Lift your right leg, with the knee bent, until the upper thigh is parallel to the ground. From your hip, drive the leg back, so that your forefoot contacts the ground, then pull the leg back up to the starting position to complete one rep. Perform in sets of 10 on each leg, gradually increasing the speed of the drive;
- **Leg cycling.** Assume the same starting position as for the exercise above, but this time, on driving the leg back sweep it back up and behind you before pulling it back from the hip to the starting position. Try to keep the foot dorsi flexed – *ie* stretched towards the leg. Perform this exercise slowly at first, gradually building up speed as you become more confident.

A final thought is – do not wear shoes! No, I am not recommending that you complete your next lactate stacker session in your socks; but, if weather permits (or you are training indoors), performing the drills described above over very short distances without shoes can be very beneficial. Running shoes prevent the calf and Achilles tendons, in particular, from optimally flexing. They also reduce the potential to specifically strengthen these areas. Increasing foot and lower leg strength can make you a more efficient runner.

Why adopt a different approach?

Here, then, in summary is why adopting a different approach to warming up could improve your sports performance:

1. You will save time and free up more specific training hours. If you were training five times a week for 250 days a year, warming up and stretching in the traditional manner for 30 minutes at a time would take up a total of 125 hours. That is virtually five days of continuous training time that could be put to much more specific use;
2. The time spent specifically warming up will also improve your running action and specifically strengthen and stretch your running muscles, so boosting your performance. The lower leg is fundamental to running performance, and many of the drills described opposite will strengthen this region and so, in turn, do wonders for your power generation and force return;
3. You will be better prepared mentally. A slow warm up with a sustained period of stretching can switch your mind away from the dynamics of the task ahead. This may be particularly detrimental before a race or competition, when you will want to maintain your focus and stay sharp. On a subtler level, your neuromuscular system may not be optimally prepared if you pursue a slower style of warm up with lots of stretching. The more focused approach will heighten the ability of your muscles to contract;
4. Over stretching your connective tissue can impair running efficiency and dynamic sports performance. If a runner becomes too flexible, perhaps in the hip and upper thigh region, energy can be wasted through inefficient leg drive and knee pick up. And these negative effects become more pronounced the faster you run;
5. Other research has indicated that the shine is knocked off dynamic activity by too much preparatory passive stretching in the warm up. Runners' legs need to be 'hard', energy efficient, force returning appliances, not spongy, over absorbent ones. Too much stretching and too great a range of movement can be a bad thing. Recent research indicates that plyometric training for distance runners will develop this energy efficiency, but so, too, will a more specific warm up;
6. Hyper mobile joints can also make you more injury prone, particularly in impact sports.

Having said all this, there are times when 'old school' stretching is okay. Despite the marginalisation of stretching in the new dynamic warm up, active, passive and PNF (proprioceptive neuromuscular facilitation) stretching still have a very important role to play in an overall training plan. If you recognise that limitations in your current range of movement are hampering the performance of your sport, you can use these methods to develop the range of movement you require. You should do this periodically, in any case, to reduce muscle shortening and the potential build up of muscle tightness. Note, however, that this is best done in separate sessions, away from your sport specific workouts.

John Shepherd

Module 4

Endurance

Introduction

Endurance is the capacity to sustain movement or effort over a period of time. Local muscle endurance is the ability of the muscles to repeat movements without undue fatigue, whilst cardiovascular endurance is the ability of the cardiovascular system to transport oxygen to muscles during sustained exercise.

Overview of the articles in this section

- Brian Mackenzie explains how to develop the energy production systems to meet the demands of your sport or event
- Danny O'Dell provides an overview of strength endurance and the ways to develop it
- Stefanos Volianitis takes a critical look at the benefits of interval and continuous training for rowers

The articles in this section are applicable to most sports.

How to develop a good solid base on which to develop speed

A good base of endurance and strength is important before the specific speed and strength requirements of the athlete's sport/event can be developed, if you wish your athlete to avoid injury. The objective of endurance training is to develop the energy production system(s) to meet the demands of the sport/event.

What are the energy production systems?

In the human body, food energy is used to manufacture adenosine triphosphate (ATP) the chemical compound that supplies energy for muscular contraction. Since ATP is in very low concentrations in the muscle, and since it decreases only to a minor extent, even in the most intense voluntary contraction, tightly controlled energy pathways exist for the continual regeneration of ATP as muscular contraction continues. For continuous exercise, ATP must be re-synthesised at the same rate as it is utilised.

There are four types of endurance: Aerobic, Anaerobic, Speed and Strength endurance. A sound basis of aerobic endurance is fundamental for all events.

The distribution of aerobic to anaerobic endurance for the runner is approximately:

Distance/Event	% Aerobic	%Anaerobic
200 metres	5	95
400 metres	17	83
800 metres	34	66
1500 metres	55	45
5000 metres	80	20
10,000 metres	90	10
Marathon	98	2

Aerobic endurance

During aerobic work (aerobic means 'with oxygen') the body is working at a level that the demands for oxygen and fuel can be met by the body's intake. The only waste products formed are carbon dioxide and water. These are removed as sweat and by breathing out.

Aerobic endurance can sub-divided as follows:

- Short aerobic – two minutes to eight minutes (lactic/aerobic)
- Medium aerobic – eight minutes to 30 minutes (mainly aerobic)
- Long aerobic – 30 minutes + (aerobic)

Aerobic endurance is developed through the use of continuous and interval running.

- Continuous duration runs to improve maximum oxygen uptake (VO_2 max)
- Interval training to improve the heart as a muscular pump.

Aerobic threshold

- The aerobic threshold, the point at which anaerobic energy pathways start to operate, is considered to be around 75% of the athlete's maximum heart rate. This is approximately 20 beats lower than the anaerobic threshold.

Anaerobic endurance

During anaerobic work (anaerobic means 'without oxygen'), involving maximum effort, the body is working so hard that the demands for oxygen and fuel exceed the rate of supply and the muscles have to rely on the stored reserves of fuel. In this situation waste products accumulate, the chief one being lactic acid. The muscles, being starved of oxygen, take the body into a state known as oxygen debt. The body's stored fuel soon runs out and activity ceases – often painfully. Activity will not be resumed until the lactic acid is removed and the oxygen debt repaid. Fortunately the body can resume limited activity after even only a small proportion of the oxygen debt has been repaid. As lactic acid is produced the correct term for this pathway is lactic anaerobic energy pathway. The alactic anaerobic pathway is the one in which the body is working anaerobically but without the production of lactic acid.

This energy pathway can exist only so long as the fuel actually stored in the muscle lasts, approximately four seconds at maximum effort.

Anaerobic endurance can be sub-divided as follows:

- Short anaerobic – less than 25 seconds (mainly alactic)
- Medium anaerobic – 25 seconds to 60 seconds (mainly lactic)
- Long anaerobic – 60 seconds to 120 seconds (lactic +aerobic)

Using repetition work of relatively high intensity with limited recovery can develop anaerobic endurance.

Anaerobic threshold

- The anaerobic threshold, the point at which lactic acid starts to accumulates in the muscles, is considered to be somewhere between 85% and 90% of your maximum heart rate.

Speed endurance

Speed endurance is used to develop the co-ordination of muscle contraction in the climate of endurance. Repetition methods are used with a high number of sets, low number of repetitions per set and intensity greater than 85% with distances covered from 60% to 120% of racing distance. Competition and time trials can be used in the development of speed endurance.

Strength endurance

All athletes need to develop a basic level of strength endurance. Examples of activities to develop strength endurance are – circuit training, weight training, hill running, harness running, Fartlek, etc.

Energy production is both time and intensity related. Running at a very high intensity, as in sprinting, means that an athlete can operate effectively for only a very short period of time.

Running at a low intensity, as in gentle jogging, means that an athlete can sustain activity for a long period of time. Training introduces another variable, and the sprinter who uses sound training principles is able to run at a high intensity for longer periods of time. Similarly, the endurance athlete who uses sound training methods can sustain higher intensities during a set period of time. There is a relationship between the exercise intensity and the energy source.

Energy pathways

D. Matthews and E. Fox, in their book, *The Physiological Basis of Physical Education and Athletics,* divides the running requirements of various sports into the following 'energy pathways': ATP-PC and LA, LA-O2, and O2.

- **ATP – Adenosine Triphosphate**: a complex chemical compound formed with the energy released from food and stored in all cells, particularly muscles. Only from the energy released by the breakdown of this compound can the cells perform work. The breakdown of ATP produces energy and ADP.
- **PC – Phosphate-creatine:** a chemical compound stored in muscle, which when broken down aids in the manufacture of ATP. The combination of ADP and PC produces ATP.
- **LA – Lactic acid:** a fatiguing metabolite of the lactic acid system resulting from the incomplete breakdown of glucose. However Noakes in South Africa has discovered that although excessive lactate production is part of the extreme fatigue process, it is the protons produced at the same time that restrict further performance
- **O2** means aerobic running in which ATP is manufactured from food, mainly sugar and fat. This system produces ATP copiously and is the prime energy source during endurance activities

These energy pathways are restricted by time. In other words, once a certain time elapses that specific pathway is no longer used. There is some controversy about these limitations but the general consensus is:

Duration	Classification	Energy supplied by
1-4 secs	Anaerobic	ATP
4-20 secs	Anaerobic	ATP + CP
20-45 secs	Anaerobic	ATP + CP + muscle glycogen
45-120 secs	Anaerobic, lactic	Muscle glycogen
120-240 secs	Aerobic + anaerobic	Muscle glycogen lactic acid
240-600 secs	Aerobic	Muscle glycogen + fatty acids

The result of muscle contraction produces ADP which when coupled with PC (stored in the muscles) regenerates ATP. Actively contracting muscles obtain ATP from glucose stored in the blood stream and the breakdown of glycogen stored in the muscles. Exercise for longer periods of time requires the complete oxidation of carbohydrates or free fatty acids in the mitochondria. The carbohydrate store will last approx. 90 minutes and the free fatty store will last several days.

All three energy systems contribute at the start of exercise but the contribution depends upon the individual, the effort applied or on the rate at which energy is used.

The anaerobic (ATP-PC) energy system

Adenosine Triphosphate (ATP) stores in the muscle last for approximately two seconds and the resynthesis of ATP from Phosphate/Creatine (PC) will continue until PC stores are depleted, approximately four to five seconds. This gives us around five to seven seconds of ATP production.

To develop this energy system, sessions of four to seven seconds of high intensity work at near peak velocity are required, *eg*

- 3 * 10 * 30m with recovery of 30 seconds/repetition and five minutes/set.
- 15 * 60m with 60 seconds recovery
- 20 * 20m shuttle runs with 45 seconds recovery

The Anaerobic Lactate (Glycolytic) System

Once the PC stores are depleted the body resorts to stored glucose for ATP. The breakdown of glucose or glycogen in anaerobic conditions results in the production of lactate and hydrogen irons. The accumulation of hydrogen irons is the limiting factor causing fatigue in runs of 300m to 800m.

Sessions to develop this energy system:

- 5 to 8 * 300m fast – 45 seconds recovery – until pace significantly slows
- 150m intervals at 400m pace – 20 seconds recovery – until pace significantly slows
- 8 * 300m – 3 minutes recovery (lactate recovery training)

There are three different working units within this energy system: Speed Endurance, Special Endurance 1 and Special Endurance 2. Each of these units can be developed as follows:

	Speed Endurance	Special Endurance 1	Special Endurance 2
Intensity	95-100%	90-100%	90-100%
Distance	80-150 metres	150-300metres	300-600 metres
No of Repetitions/Set	2 to 5	1 to 5	1 to 4
No of Sets	2 to 3	1	1
Total distance/session	300-1200 metres	300-1200 metres	300-1200 metres
Example	3 * (60, 80, 100)	2*150m+2*200m	3 * 500m

The aerobic energy system

The aerobic energy system utilises proteins, fats and carbohydrate (glycogen) for resynthesising ATP. This energy system can be developed with various intensity (Tempo) runs. The types of Tempo runs are:

- **Continuous Tempo –** long slow runs at 50-70% of maximum heart rate. This places demands on muscle and liver glycogen. The normal response by the system is to enhance muscle and liver glycogen storage capacities and glycolytic activity associated with these processes.
- **Extensive Tempo –** continuous runs at 60-80% of maximum heart rate. This places demands on the system to cope with lactate production. Running at this level assists the removal and turnover of lactate and body's ability to tolerate greater levels of lactate.
- **Intensive Tempo –** continuous runs at 80-90% of maximum heart rate. Lactate levels become high as these runs boarder on speed endurance and special endurance. Intensive tempo training lays the base for the development of anaerobic energy systems.

Sessions to develop this energy system:

- 4 to 6 * 2 top 5 minute runs – 2 to 5 minutes recovery
- 20 * 200m – 30 seconds recovery
- 10 * 400m – 60 to 90 seconds recovery
- 5 to 10 kilometre runs

Energy System recruitment

Although all energy systems basically turn on at the same time the recruitment of an alternative system occurs when the current energy system is almost depleted. The following table provides an approximation of the percentage contribution of the energy pathways in certain sports. (Fox et al 1993)

Sport	ATP-PC and LA	LA-O2	O2
Basketball	60	20	20
Fencing	90	10	
Field events	90	10	
Golf swing	95	5	
Gymnastics	80	15	5
Hockey	50	20	30
Distance running	10	20	70
Rowing	20	30	50
Skiing	33	33	34
Soccer	50	20	30
Sprints	90	10	
Swimming 1500m	10	20	70
Tennis	70	20	10
Volleyball	80	5	15

Brian Mackenzie

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.' [1] 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.

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.

There are muscle fibres that are not what you would call exclusively fast twitch or exclusively slow twitch. [2] They are a combination of the two not fully fast twitch or fully slow twitch. But, strengthening these muscle fibres will enable a greater expression of strength endurance to occur.

Another aspect to this particular strength continuum is dynamic and static strength endurance enhancements can be improved by following proper training schedules. The athletic movements and the muscular tension displayed during these movements distinguish between these two forms of strength endurance. Endurance is thus a matter of dividing muscle tension into large or moderate magnitudes and the length of time for each.

Dynamic strength-endurance is typically associated with cyclic exercises in which considerable tension is repeated without interruption during each cycle of movement. It is also apparent in acyclic events requiring maximum power repetitions with short rest periods between such as jumping or throwing activities.

Static strength-endurance implies isometric tension of varying magnitude and duration or in holding a certain posture. Static strength endurance is associated with relatively long or short term sustained muscular tension, its duration in each case being determined by its magnitude.

These can be further broken down into general strength-endurance and local strength endurance. Both of which depend upon how many muscle groups are involved in the activity.

For example general strength endurance is build around the utilisation of large muscle groups to power the activity such as the case with rowing, where, for example, the quads, gastroenemius, biceps, triceps, deltoids and the Latissimus dorsi muscles predominate the scene.

In local strength endurance, a particular muscle group is targeted for improvement based upon its use during the sport. An example would be the upper body muscles of the chest and upper back, deltoids, and the triceps for a bench press using body weight for repetitions contest.

Further examination will lead to differentiations in measurement. Do we measure absolute, static, acceleration, or explosive strength endurance?

If measuring absolute strength endurance then the overall result would not consider the level of development of the separate motor abilities. If the object of the measurement is partial endurance then 'the level of development of specific motor abilities calculated when the influence of other abilities is in some way excluded.'

As a practical matter when determining partial endurance in a strength exercise a weight requiring exertion at a percentage of one's maximum one repetition is used. It must be statically held, (static strength endurance) or moved to failure in a repetitive manner, which indicates dynamic strength endurance.

An incomplete index follows if there is either no correlation with maximal strength or a negative correlation between the two tests. Where a person is able to raise the same weight the relationship to absolute strength and maximal strength has a high correlation.

To set apart the differences between lifters, the load lifted of each one must be divided by the body mass of the individual subjects. Strength endurance is highly specific to muscle activity.

Special work capability of strength endurance is expressed mainly in the cyclic events, which are those requiring powerful repetitions in a constant recurring fashion. In the acyclic sports arena the ability to exert powerful muscular motion in the static form is even more pronounced. Take for example, the wrestler holding his opponent, and then overpowering him for the point or match win.

Forming the base of strength endurance is general endurance. The best way to develop strength endurance is under the most demanding conditions and that is through the simulation of contest conditions or in high volume workouts. This does not however preclude the use of special strength exercises to help build the strength base of the athlete.

Strength endurance program

Here is a brief example of a strength endurance program used with great success by the Soviet athletes prior to the collapse of the Soviet Union in the early 1990's.

Start with three sets of three repetitions at 80% to 90% of a one Repetition Maximum (1RM) with rest of two to three minutes. Then drop the weight to 40% to 50% 1RM and perform four sets of fifteen repetitions each in a medium to slow pace.

At a weight of 40% to 50%, perform the maximum number of lifts you can in twenty seconds, rest twenty to thirty seconds, and then repeat for one to two extra sets. Maintain pulse at 120 to 140 beats per minute. (Authors suggestion: Maintain your pulse at around the 80% target heart rate levels.)

Perform eight to ten different circuit exercises in a medium to slow pace with thirty to sixty seconds of rest between exercises. Keep pulse below 140 repetitions. (Authors suggestion: Maintain your pulse at around the 65% to 70% target heart rate levels.) Choose exercises common to your sport.

As an example of the wrestler's circuit, these exercises are performed according to the schedule above in a twenty-minute time span.

- Squat
- Bench press
- Sit ups
- Dumbbell Fly's
- Upright rows
- Twists with bar on the back-be extremely cautious of this exercise. Make certain your back is braced with your stomach. I am not referring to using a weight belt!
- Pull overs
- Biceps curl
- Bent over rows
- Shoulder press

This circuit illustrates a method of improving all strength endurance fibres.

In summary, the late Mel Siff states an 'objective, reliable means of evaluating strength endurance in sporting activity has not yet been devised.' Keep that in mind as you contemplate the results of the research available in the field of strength and conditioning.

Danny O'Dell

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Which works best, interval training or steady state?

The dictionary defines an interval as a period of time or a specified distance. Well, that is true, but for us rowers it means repeated bouts of high intensity rowing with intermittent rest periods. In endurance training circles, no matter what the sport, interval training has become standard practice. Since the 1960s, it has come to be thought of as the key to endurance performance success. In some training programs, it accounts for 50 to 75% of the total training volume. Let us try to take a critical look at this line of thinking and see how much of this practice is justified for rowers.

The physiology of interval training

In recent laboratory studies, athletes were asked to accomplish a certain amount of work (force x distance, a quantity that can be precisely measured on the ergometer) in one hour. This work could be done either by a continuous bout of exercise at a power output of 175 Watts, or by intermittent exercise at a heavier load, separated by regularly spaced rest intervals. A double power output was chosen for this heavier load. Thus the desired work could be accomplished with 30 minutes of exercise at 350 Watts within the space of one hour. At a work load of 175 Watts, the athletes could easily exercise for one hour continuously. Heart rate was only 134 bpm, VO_2 was 55% of maximal, and blood lactate remained near resting levels. When the athletes tried to exercise for as long as possible at 350 Watts, or double that workload, the exercise could only be maintained for nine minutes. Heart rate was 190 bpm (maximal), VO_2 was at max, and blood lactate rose to 16.5 mM, an extremely high value indicative of extreme fatigue.

If, instead, they exercised at the same 350 Watts intermittently for a duration of between 30 seconds and three minutes, always with equal rest, they could perform the desired work within the hour. However, the physiological responses differed tremendously depending on the interval duration. There were two major conclusions:

1. Intermittent exercise allows a higher total volume of high intensity work. Performing continuously, the athletes could only manage nine minutes at 350 Watts. Performing in three minute intervals, they could accumulate over three times as much total work (30 minutes, with great effort)
2. When the intervals were three minutes in length, the desired work could be accomplished within one hour, but with great effort. However, when the work and rest periods were shortened, the physiological strain was dramatically reduced, even though total oxygen uptake during the hour was not markedly lower. Specifically, if the intervals are less than two minutes in length, the physiological workload/stress is severely reduced despite the same accumulated time (30 minutes here) and the same interval intensity (350 Watts here)

Why are the responses so different?

During very brief intervals, oxygen bound to myoglobin served as an effective buffer against the accumulation of an oxygen deficit (and lactic acid) during the exercise bout. Thus after a 30 second bout, myoglobin oxygen stores were repleted during the rest period, and the peak demand on oxygen delivery was not severe. By analogy, the body manages to live expensively, and briefly deplete cash reserves, but then always repays the small debt during a subsequent 'debt recovery period'. No long term debt accumulates. As the exercise bout lengthens, the capacity of the small buffering myoglobin oxygen store is outstripped, lactic acid production and accumulation become significant, and the burden of greater oxygen delivery during the work interval falls on the cardiovascular system. Subsequent experiments showed that if you shorten the work and rest periods to smaller and smaller intervals, it is possible to perform at even higher power outputs without accumulating lactic acid or severely stressing the cardiovascular system.

Conclusions so far

For a period of intermittent exercise that approximates to a VO_2 max workload to overload the cardiovascular system effectively, it needs to be of at least two minutes duration due to (1) lag time in the cardiovascular response and (2) the oxygen buffering effect of myoglobin. Previous studies have suggested that interval training is the best way to enhance maximal cardiac performance and thus, presumably, VO_2 max. This improvement occurs without any change in skeletal muscle oxidative capacity.

Interval training allows us to accumulate a greater volume of stress on the blood pumping capacity of the heart. By using a large muscle mass, we promote maximal stroke volume responses. A high heart rate is also achieved as a function of the intensity. Finally, the periodic elevations and decreases in intensity may create special loading stresses on the heart, which are adaptive. For example, during an interval, heart rate climbs high, then at the moment you stop the interval it immediately starts to drop but venous return remains high. These exposures to additional ventricular stretch may help trigger ventricular remodelling (bigger ventricle volume).

So, high intensity intervals all the time?

Not exactly. For the untrained, interval training is a way of accumulating minutes of exercise at a higher intensity than our skeletal muscles are initially adapted to tolerate. In the untrained, the heart is better conditioned to endurance performance than the skeletal muscles; thus it needs a greater overload to adapt maximally. Intermittent high intensity training is also a powerful stimulus for increasing blood volume, which is a critical adaptation that contributes significantly to improved maximal cardiac output and VO_2 max. BUT here is the major pitfall of the all interval mentality. VO_2 max is only the first wave of performance improvements for the rower. VO_2 max plateaus quite early in the rower's career. So the key question is whether hard interval training is also the best approach to improve the other components of rowing for more advanced rowers.

Improving the endurance capacity of the skeletal muscles

The second wave of improvements is that to lactate threshold. Changes in this occur over a longer time course than improvements in maximal oxygen consumption. The site of adaptation moves from the cardiovascular system to the skeletal muscles. These adaptations occur progressively over a period of several years. But the most powerful stimulus for change in skeletal muscle aerobic capacity is quite different from the most powerful stimulus for cardiac function changes. Hard but short interval training fails here. We MUST put in the hours of continuous constant intensity rowing to maximise these adaptations. This will range from steady state efforts at 65 to 75% VO_2 max lasting 45 to 120 minutes to repeated anaerobic threshold work at 80 to 90% VO_2 max for 15 to 30 minutes.

Extensive data collected on rowers in the German national team by their own physiologists indicate that 80% of their training volume was performed at a lactate concentration of under 2.0 mM (or only slightly above resting levels). Only one or two per cent of their training volume was at race pace! Back in the 50s and 60s, the Germans (and the Soviets) trained at brutal intensities and those who did not survive were replaced. What they found with this training program was that the rowers reached high performance levels but did not show progressive improvement from year to year. Every year they came up to the same level, fell back in the off season, and repeated the process the following year. Then the coaches changed the composition of the training to higher volume, lower intensity work (fewer killer intervals at max speed) and the long term progress began to take place.

The body's tolerance of exposure to very high lactate concentrations is quite limited. After a severe effort, immune function and other measures are disturbed for days. After a major international race, the disturbance can last for weeks. Overtraining and tissue injury are much more likely during periods of extreme intensity. If training is interrupted by injury or staleness, then no progress is made. High intensity work must be applied in careful, infrequent doses.

What about older athletes?

Most veteran athletes do not train twice a day, nor even every day. That is what having a full time job does for you (or is it the wisdom to listen to the body when it says 'I need a day off'?). But the best vet rowers still put in a lot of hours doing moderate to hard steady state rows on the water or on the erg. One ergometer rower who briefly held the world record in the men's 50+ age group reported 140 rows of one hour continuous on the ergometer in the year prior to his world record. The intensity of these rows was about 73 to 75% of his 2500 metre race power, based on the metres rowed each session. This pace is about 75 to 80% VO_2 max. Almost no training at higher intensities was performed until the weeks prior to a series of spring races. Then he proceeded to break 7:56 for 2500 metres four times in one month, culminating in a 7:52 world best! It is also worth pointing out that his performances steadily improved over about five years; despite being middle aged (he discovered rowing in his 40s).

So, no interval training ever?

Well not exactly. First, interval training of above 100%VO_2 max will not provide additional stimulus for improving maximal aerobic capacity, or lactate threshold, and may hurt. There is substantial research to indicate that there is little or no difference in the impact on maximal oxygen consumption among exercise intensities ranging from 80 to 100% of VO_2 max. At intensities above 100%, the stimulus for improving maximum oxygen consumption is actually reduced because of dramatically decreased training volume and the inhibiting effect of lactic acidosis on cellular oxygen utilisation. During work between the 75 to 100% intensity range, improved exercise tolerance should be compensated for by increasing distance or time, not intensity. This increased tolerance for exercise at a given submaximal intensity is indicative of skeletal muscle adaptations.

Second, aerobic interval training is definitely effective, but the emphasis should be on interval durations of from 10 to 20 minutes for rowing events longer than four minutes. Intervals of four to eight minute duration are going to be at intensities of 85 to 100% VO_2 max. This intensity and duration is optimal for maximising/ maintaining cardiovascular power.

However, remember that this adaptation plateaus early. Your incorporation of four to eight minute intervals probably need not ever exceed once every eight days. Consequently, the majority of your training time should be aimed at optimising the signal for other adaptations. Longer intervals of 10 to 20 minutes duration will be at 75 to 80% depending on your ability and training status, and are a very useful method for developing skeletal muscle endurance. With both intervals the duration will generally force you into the right intensity range, if you are making a real effort. The intermittent nature will help you to accumulate minutes of high quality work. 24 to 32 minutes of accumulated interval time are appropriate for most of us when performing the four to eight minute intervals; there will be little or no benefit from longer sessions.

For the longer, lower intensity intervals, I think 40 to 60 minutes is ideal. Twenty to forty minutes will probably do most of the job. This means that on most of those busy days when you only have 30 minutes to train, a brief warm up and one hard 20 minute steady state interval (tempo run, AT effort, etc.) will be more beneficial than resorting to a series of very short intervals. Rest periods do not need to be very long since lactate accumulation is not severe. For example, if you are attempting to do five times five minutes, a rest interval of at least two minutes but no more than four minutes should be used. For 20 minute intervals, rest will only be five to six minutes. If the intensity is appropriate for a given interval session, you should be able to complete all the intervals at the same speed.

Stefanos Volianitis

Module 5

Strength

Introduction

'Strength' is a generic term used to describe many dissimilar abilities. We only use the same word because historically no one has provided us with simple alternatives.

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

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.

Overview of the articles in this section

- Mike Winch explores how strong an athlete needs to be to meet the demands of their sport or event
- Walt Reynolds provides a selection of strength training exercises that will help endurance athletes improve their stride length and foot strike frequency

- Raphael Brandon explains how strength training can improve kicking power, sprint speed and jumping ability
- Brian Mackenzie explains how to monitor for muscle imbalance

The articles in this section are applicable to most sports.

How strong do your athletes need to be?

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 lump strength attributes together as if we are looking for the same result for each event. This is exacerbated by coaches who are too busy to delve deeply into detailed information on strength training, and who are generally happy to accept what a few often inexperienced advisors put forward. But this can be ultimately damaging to the athlete since an incorrect bias to one type of strength instead of to another can completely distort the physical capabilities of that athlete.

Take for example the 'strength' needed by a ten thousand metre runner compared with that of the shot-putter. Are they the same? If not what is the difference?

Simply put, the word 'strength' covers many abilities, and before any attempt is made to apply 'strength' training the word itself and therefore what it refers to, must be fully understood. Scientifically we understand the needs of our athletes quite clearly. The ten thousand metre runner needs the 'strength' to carry his or her body weight around a track for twenty seven and a bit laps. The shot putter needs the 'strength' to accelerate him or herself across 2.1 metres of circle and putt a 7.26kg ball a decent distance. They both need to be 'strong', but is it the same 'strength' that is required? Intuitively we know it is not and yet our language is inadequate in specifying the differences.

To understand what is going on we need a basic knowledge of physiology and how this operates for each event. The runner in our example is in an aerobically based event that requires the sustained application of a minimal force using a technically very simple movement. At certain stages during the race and particularly over the last few laps an injection of speed resulting from increased force application is needed, but at no time is the athlete required to generate maximum power.

For the shot putter the event requires a completely different set of competences. He or she must generate maximum force during a complex movement, culminating in an explosive one-sided effort.

The 'strength' training for each of these events must therefore be totally different, and an adequate model for that 'strength' needs clearly to be the basis for session design.

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

Several years ago I was able to conduct some research into the speed and force of muscle contraction using advanced hydraulic equipment. The results were very interesting. I tested every athlete that came into my gym and measured how much force their quadriceps could generate and at what speed. There was a huge difference between athletes and the results closely related to the event they performed. The marathon and long endurance athletes had slow speed and could only generate their maximum force slowly. The shot-putters were very fast (at least 50% faster) and could generate maximum force very quickly.

These measurements also were able to distinguish a good athlete in his or her field from a mediocre athlete. The tests were simple and quick, and naturally if the athlete showed a result which indicated that they could never make the grade then that viewpoint was not expressed. However it gave me confirmation of my efforts as a coach since the results fitted closely with the level of competitive performances of the athletes with whom I worked.

The other interesting result was that after general non-specific 'strength' training all athletes improved in the test and reported feeling 'stronger' while performing their event. Even the endurance runners expressed an improved feeling of 'strength'.

This you might say contradicts what I started this article off by saying, that each event has very different 'strength' requirements. It is however a matter of degree and balance. The endurance runner would of course benefit from general heavy weight training initially because in general their bodies are light and weak and the athletes do not have any significant absolute dynamic strength base. The throwers would benefit because the events depend heavily on absolute dynamic strength. If however, the runner were to continue to try to gain absolute dynamic strength, his or her muscles would get bigger and the energy used in carrying the extra weight would reduce performance. The shot-putter on the other hand can continue to work at heavy weights and only after several years needs to move more towards specific weight training. The throwers would continue to increase dynamic absolute strength throughout their career, whereas this would be counter-productive for the endurance runner beyond the point of effective improvement with minimal weight gain.

This all sounds very complicated and abstract, but it is nevertheless at the heart of training athletes. The simplest way to assess where you are on the general weight training playing field is to apply simple tests. Some of the best are the simplest. For example standing long jump measures fairly accurately the leg power compared with bodyweight (power/weight ratio), or simply the ability to apply absolute dynamic strength as quickly as possible. The distance jumped gives a good indication of whether the athlete is strong but too heavy, light and weak or on the right line of improvement, and can be used by endurance runners as well as the other events.

This simple measurement can save a lot of wasted effort and time, as can measuring performance in three consecutive two footed 'bunny' jumps, which gives an indication of reactive strength.

As with all aspects of our sport, success comes from the correct application of training methods and understanding how much of each ingredient you need for your particular event. The essence then of 'strength' training is therefore to be able to assess when too much of one aspect of training is no longer producing positive results. It is like the old endurance training argument about which is better, long slow distance training or shorter faster runs. The answer is as always in sport, neither, you need a balance of both. It is the same with 'strength'; know what you want and how to train for each different type, apply the schedules in a balanced way and then test each element to see if it produces the right result. Also assess whether the overall performance is improving by using specific event tests. If not, change the balance, and do not be afraid of saying you were wrong and that an alteration in strategy is needed. No event or athlete needs exactly the same balance of ingredients to produce the best result.

'Strength' training can be your major path to success, but it can also be a quick road to disaster.

Mike Winch

Three strength-training exercises to improve stride length and frequency

If you are an endurance runner, should you carry out regular strength training workouts? Not a single published scientific study has linked resistance training with improved 5k, 10k or marathon times, but running books and magazine articles extol the merits of strength training, and countless runners spend time in the weights room.

Proponents of strength training for endurance runners claim that the activity bolsters muscle power, raises tendon and ligament strength, and lowers the risk of both acute and chronic injuries. On the other hand, critics of the ‘iron game’ point out that most resistance exercises are mechanically dissimilar from running. They complain that strength-training manoeuvres, most of which require just seconds to complete, cannot possibly promote improved muscular endurance during a sustained, longer duration activity like a 10k race or marathon. They also suggest that weight training may decrease flexibility and produce unproductive increases in muscle mass and overall body weight. They frequently call attention to the fact that highly successful runners tend to be small and reed thin, the exact opposite of the strength trained athlete.

To date, much of the research exploring the link between strength training and endurance performance has focused on standard exercises such as leg extensions and curls, leg presses, bench and shoulder presses. Along with double leg squats, these are the same exercises which runners emphasise during their resistance training workouts. Overall, the exercises do a good job of developing generalised muscle tone and strength, but despite their popularity, no research has ever determined that they improve endurance running capability.

In fact, it is difficult to understand exactly how these standard resistance exercises would promote better endurance performances. Running involves multiple joint actions and forces, numerous muscle groups in the hips, legs, ankles, and feet to work concurrently to maintain control and balance. Weight training tends to focus on isolated muscles and ignores the complex, co-ordinated motor patterns required for running.

Take a common resistance exercise employed by runners, the knee extension. For this activity the runner remains in a seated position, their hips are relatively immobile, and their ankles are locked in position. True, the quadriceps muscles are active, but they work in almost total isolation from the rest of the leg, the exact opposite of what happens during running. Since knee extensions are totally non-weight bearing and have little specific resemblance to running, some faultfinders have scoffed that this traditional exercise will help you move faster – whenever you attempt to run sitting down!

The point is that knee extensions will make your quads stronger during knee extension workouts, but they may not make your quads more powerful during a 10k or marathon, when the actual contractions of the quads are of a different magnitude and frequency. The quads are forced to act in concert with the other muscles in the legs.

Since traditional resistance routines are of doubtful value because of their lack of similarity to running, what kind of strength training should you employ? To answer this question, it is important to remember that all competitive running events require the development and maintenance of speed over a specified period of time. Running speed is largely dependent on the amount of force applied to the ground during each foot strike, and the time over which that force is applied. The greater the force of a foot strike and the shorter its period of application, the higher the power of an individual step and the faster the speed of a runner.

By increasing the power exerted during each step, runners raise the speed of their workouts and races. The power requirements for a marathon are lower (and running speeds slower), compared to a 5000 metre race, but both events require optimal power production during each foot strike.

A lot of the power produced during running depends on the mechanical ‘energy return’ properties of a runner's feet and legs. The muscles and tendons of the lower extremities act like springs during running, mainly by storing energy just before and during the compression associated with foot strike and then releasing (‘returning’) this energy during take off. This return of energy is influenced by both the elasticity of the muscles and tendons and by nerve cells which control muscle and tendon flexibility.

Better nervous system control of the muscles of the lower limbs should produce higher levels of elasticity and improved energy return. Resistance exercises aimed at improving running performance should not just attempt to increase general muscle strength they should enhance specific activities of the nervous and muscular systems, which promote faster, more co-ordinated movements. (See D. Schmidtbleicher's analysis in *Strength and Power in Sport*, edited by Paavo Komi: 381-395, Blackwell Scientific Publications, London).

What is really needed is specific strength training for runners, exercises that target the muscles and neuronal pathways responsible for actual energy return during running. Although this may sound complicated, it should not have to be in actual practice, and it is not. In the paragraphs that follow, you will find three key power building exercises that are easy to carry out, will not take much of your time, and will rejuvenate your running because they replicate key motor movements involved in the process of running.

The Power triad

These three exercises should be performed in the order in which they are presented, and only when you are well rested. Specific strength training aims for positive adaptations of the nervous system as well as the muscles. Completing the exercises when you are over tired leads to poor neuromuscular co-ordination and movements that are slower than desirable.

That means that the trio of specific exercises should be completed before a running workout, not after, and in fact the best possible time is immediately before an interval, economy, or lactate threshold session, not before a slower workout. While that may sound paradoxical (some might fear that strength training would slow down a subsequent training session), the truth is that positioning the exercises right before your high intensity workout will help you run faster. In fact, at least five different scientific studies have shown that a high intensity strength session activates the nervous system, increases the 'firing rate' of nerve cells which control muscles, and improves the overall 'recruitment' of muscle fibres during a workout (see Paavo Komi's 'The Stretch-Shortening Cycle and Human Power Output', in L. Jones, N. McCartney, and A. McCornas, eds., Human Muscle Power: pp27-42, *Human Kinetics, Champaign, Illinois*).

One final caution: perform the third exercise, 'One Leg Hops in Place', only on an aerobics floor, wooden gym floor, grass, a rubberised track, or any resilient surface which offers some 'give'. Hopping repeatedly on concrete or asphalt may increase the risk of overuse injuries to the lower leg and shin.

Using the eight-week program below as your guide, here are the three key exercises:

1. **The high bench step up:** This exercise strongly develops the hamstrings, with complimentary development of the gluteals (the 'buttock' muscles) and the quadriceps. Simply 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. as shown in the training program, 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).
2. **One leg squat:** This exercise strongly develops the quadriceps and gluteals, with a complimentary boost to the hamstrings. To complete one leg squats in the correct way, 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 six to eight 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 degrees 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.

3. **One leg hops in place:** This exercise builds strength and co-ordination in the entire lower extremity, including the foot, ankle, shin, calf, thigh, and hip. The resilient, bouncy nature of the exercise makes it the most specific of the three and extremely close to the actual movements involved in running. Simply start from the same position you used for the one-leg squat, with the toes of the right foot supported by a six to eight 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 as shown in the training program. The left knee should rise about four to six 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.

Why hop on one foot instead of bounding from foot to foot, as runners usually do during their drills? For one thing, it is very difficult to move fast while you are bounding, so bounding is not very much like sizzling through a 5k or 10k race. By contrast, you can move very quickly during the one-leg hops, so your power expands dramatically and your co-ordination during high speed running improves greatly. Eventually you will learn to move more quickly and efficiently. Research by Russian scientists indicates that one-leg hopping is far superior to bounding at inducing improvements in leg speed (‘Muscles and the Sprint’, Legkay Atictika, No. 5: 8-11, 1992, cited in *Fitness and Sports Review International*: 192-195, December 1992).

For similar reasons, the one leg squat is superior to runners' traditional exercise the two legged squat. While a much greater load can be hoisted on the shoulders during a two-legged squat, that weight is distributed through two legs, not one, so the actual resistance per leg is often less. In addition, the trunk of the body is often inclined significantly forward in a two legged squat but remains nearly vertical in a one-leg effort, so the latter more closely parallels the form required for running. Plus, for purposes of maintaining balance, the feet are often angled outward during the two-leg squat, which is unnatural to running, while the feet point straight ahead during a one-leg effort. Overall, the one leg squat has the added advantage of being safer, since less total weight is used.

The first exercise, the high bench step up, is like climbing hills in the comfort of your own home or gym. You are basically lifting your body repeatedly against the force of gravity and powering your hamstrings, quads, and gluteals in the process. Like hill workouts, the step up should improve your running economy.

Overall, the strength building triad carries little risk of injury, takes little of your time, and is very specific to the actual act of running. The three exercises will improve both your co-ordination and leg muscle power, and after several weeks you will notice that your legs feel much stronger and that your stride length and frequency have improved. You will move quickly and aggressively from one foot to the other as you run, and you will reach the finish lines of your races in faster and faster times.

An 8 week strength training program for the 5k, 10k and marathon

	Weeks 1-2	Weeks 3-4	Weeks 5-6	Weeks 7-8
Exercise	**Introduction**	**Strength Endurance I**	**Strength**	**Strength Endurance II**
Step Up	15 reps/no wt	15 reps/10%	15 reps/10%	25 reps/10%
	15 reps/no wt	20 reps/10%	10 reps/15%	30 reps/10%
	15 reps/no wt	10 reps/15%	7 reps/20%	20 reps/15%
One Leg Squat	15 reps/no wt	15 reps/5%	15 reps/5%	25 reps/5%
	15 reps/no wt	20 reps/5%	10 reps/10%	30 reps/5%
	15 reps/no wt	10 reps/10%	7 reps/15%	20 reps/10%
One leg hops in place	10 secs	20 secs	10 secs	30 secs
	10 secs	20 secs	10 secs	30 secs
			10 secs	

How to read the table:

For each exercise, note that you utilise two or three sets per workout. For example, during weeks 1-2 with the step up exercise, you would complete 15 repetitions with no weight ('no wt'), rest for two minutes, complete 15 repetitions with no weight again, rest for two minutes, and then carry out a third set with 15 repetitions and no weight. After a rest, you would move through the three sets of one-leg squats and then finish the workout with two sets of one-leg hops in place. '%' represents the approximate percentage of body weight added to the exercise by carrying dumbbells in your hands.

Example:

Body weight is 140 pounds:

- 5% = 7 lbs. Use two 3lb dumbbells.
- 10% = 14 lbs. Use two 8lb dumbbells
- 15% = 21 lbs. Use two 10lb dumbbells
- 20% = 28 lbs. Use two 15lb dumbbells.

Rest Intervals:

- two minutes between sets of Step Ups and One Leg Squats
- three minutes between sets of One Leg Hops in Place
- three minutes between exercises

Progression:
After completing the above program, repeat week's 3-8 using weights, which are five to ten pounds heavier.

Strength-training program: summary

Frequency:
Twice a week on non-successive days, such as Monday and Friday, or Tuesday and Saturday, immediately prior to speed training, running economy, or lactate-threshold sessions.

Training Time Required:
20 minutes per session, not counting warm up time

Equipment Required:

1. A sturdy bench of approximately knee height,
2. A low step or block, about six to eight inches high, and
3. Free weights (dumbbells) in three to five pound increments up to about 10% of body weight

The Warm Up:
Warm up for 10 minutes by performing light jogging, stretching, and range-of-motion activities for the trunk, low back, hips, quadriceps, hamstrings, calves and Achilles tendons.

Exercise Technique:
Maintain an upright posture with your trunk at all times, and use smooth, controlled movements not out of control jerks. Devote the first two weeks of the program to the development of proper technique. As your skill at carrying out the exercises improves over time, increase your movement speed to near maximum while maintaining balance and upright posture. The idea is to exert high amounts of force in a short period of time, because that is what will give you an explosive foot strike during running and improve both your stride length and frequency.

Walt Reynolds

Strength training for field sports

The benefit of strength and strength training for footballers is well supported by research. For example, De Proft and colleagues had one group of Belgian professionals perform extra weight training during the season. Compared to a control group of colleagues who did no extra training, the players improved their kicking power and leg strength. In addition, British researcher Thomas Reilly showed that the stronger players outlasted the weaker players in terms of a regular place in the team, and had reduced injury risks. He recommends that leg strength in particular is developed, especially in the quadriceps and hamstrings, to help stabilise the knee joint, which is the most frequently injured joint in football. Peter Apor, a Hungarian researcher who has been involved in long-term studies of Hungarian professionals, agrees, saying that knee-extension torque has been associated with success in the game and that strong hamstring muscles in relation to quadriceps are crucial to knee injury prevention. Another common football injury is hernia, for which the best protection is developing strong abdominal muscles.

From this brief review of the research, we can conclude that strength and strength training, especially in the legs and trunk, are important for footballers who want to improve kick performance and reduce the risk of injury. To increase general strength, a workout consisting of leg press, leg extensions, leg curls, bench press, lat pull downs, abdominal and lower back exercises, would be ideal. This can be done with multi-gym equipment, which is also safe and easy to use. In my experience, some professional players use the club's gym equipment to perform this kind of workout after their official training session. Reilly found that players who voluntarily performed extra strength training were the ones who suffered the fewest muscle injuries. Therefore, since maintaining a fully fit squad can be a big problem, it makes sense for clubs to encourage or schedule general strength training for all players.

And sprint times, too

Another piece of research – by Taiana and colleagues in France – showed that a 10-week leg-strength training program for footballers improved their 10m and 30m sprint times and their vertical jump performance. These motor tasks are obviously very valuable. However, this study used a training program that targeted maximum strength with heavy resistances. Although this type of training is a proven method for enhancing sprint speed and jumping power, it is also difficult to include in the regular training program of a football team, because the recovery required after heavy resistance training might interfere with the regular competitions during the season.

As with strength training the value of good sprinting speed for footballers is well supported by research. Ekblom found that the absolute maximum speed shown during play was one of the parameters that differentiated elite players from those of lesser standard. This is supported by a study with German division-one players by Kollath and Quade. They showed that professionals were significantly quicker than amateurs over 10m, 20m and 30m. The acceleration difference to 10m was especially significant. This suggests that better players need superior acceleration and maximum speed to play at a higher level. Interestingly, the 30m speed was similar for the German professionals regardless of position.

The training regimes of footballers must therefore reflect this need for good acceleration and maximum speed. Peter Apor suggests, in making fitness recommendations for footballers; that players need to develop the musculature of a sprinter. I have already mentioned the benefit of maximum leg-strength training with heavy resistances for developing acceleration and speed. Taiana says that the players he trained for maximum leg strength were able to play at the weekend without detriment if the strength workout was on Tuesday. This once-a-week routine was still found to be beneficial. However, this type of training should be used with caution. Two or three sessions a week during the off-season would bring about much greater gains in maximum strength. Taiana therefore recommends that this type of training should be used in the off-season and then maintained with one workout per week once the competitive season has started.

Step by step

Another point to remember is that maximum strength training should be a progression from general strength training with submaximal loads. Heavy maximal resistance exercise, while very effective, is for advanced strength trainees only. Zatsiorsky recommends that good abdominal and lower back strength are essential if heavy lifting exercises are to be used. Thus the first step for improved sprint speed is ensuring a good basic level of strength. American trainers George Dintiman and Robert Ward recommend that an athlete should be able to perform one maximum leg press of at least 2.5 times body weight, and have a hamstring to quadriceps ratio of least 75-80%. Both these measures can be tested on the standard gym machines. Good abdominal and lower back strength are also essential for sprinting speed, as the trunk muscles are required to stabilise the sprinting movement.

Hop, bound and jump

Plyometric exercises are another proven training method that enhances leg power and sprinting speed. McNaughton cites soccer as one of the many games where short, explosive power is required, and that plyometric training is a useful complement or alternative to strength training to achieve this. Once the players are used to it, plyometrics may be more convenient than weights for speed development in terms of scheduling during the season.

Plyometric exercises are typified by hopping, bounding and jumping movements. These exercises demand a high force of contraction in response to a rapid loading of lengthening muscles. For this reason, they should be more accurately called reversible action or rebound exercises. The training effort increases the force production in the muscles, but the movements are performed at faster speeds than weight-training exercises. Thus rebound exercises are more specific to the sprinting and jumping movements in football. These exercises should be done in three to five sets of eight repetitions for each leg, with at least one minute's rest between sets. The quality and speed of the movement is the priority. The other training element that is required for improving sprinting speed is sprinting itself. This should be done with maximum efforts over 30-60m. Again, at least one minute's rest between runs should be allowed so that quality can be maintained. Remember, with this kind of training the aim is to develop the maximum speed; endurance should not become a factor. Sprinting done uphill, with weighted jackets, or towing weights is also useful because it adds resistance to the sprint movement, placing greater load on the muscles in the most specific manner. Again, short distances with long rests are recommended.

Fitting it in

I have discussed research that shows the importance of strength and speed for elite football performance. From this I have suggested four types of training:

1, General strength training to help prevent injuries, improve kicking performance and provide the basis for good sprinting speed
2. Maximal leg-strength training, which is a progression from general strength training for advanced trainees only, but one that is extremely useful for developing speed and power
3. Plyometric training exercises, which complement strength training as an effective alternative
4. Maximum sprint running over short distances with or without added resistances

The main question that now needs answering is: how can this training best be scheduled into an already full training and competing program?

Plyometrics and sprint training are usually performed when fresh. However, as it is a requirement of football to be able to sprint when fatigued, one could argue that sprint work should be done after a training session. One answer could be a short but high-quality hopping, jumping and sprints workout after a skills session. For example, 3 x 8 squat jumps, 3 x 8 skips for height, 3 x 8 hops for distance each leg, 3 x 30m towing runs and 5 x 40m sprints would be a short but useful workout if performed once or twice a week throughout the season.

Scheduling strength-training workouts is more difficult. If the program is weekend matches only, then players could do a general strength-training workout on a Monday and Wednesday afternoon, leaving plenty of time to recover for the weekend match. However, if there are midweek fixtures, then strength training may have to be sacrificed or reduced to light workouts purely to maintain strength.

The best way for a player to develop his strength would be to start a strength-training program in the off-season. Three strength workouts a week would result in improvements. Once the pre-season training starts, the player can reduce to twice weekly and then fit in workouts when possible during the season. This way the player can maintain the strength gains made during the summer.

Maximum strength exercises should only be targeted during the off-season. Afterwards, they should be done only once a week to maintain strength during the season. Maximum strength can only be achieved if it is concentrated on, and training for it can interfere with other important activities.

With careful planning and careful selection of exercises, keeping sessions short but high quality, extra training should be practicable, although sensitivity to the training status of the players is important when prescribing extra sessions.

Raphael Brandon

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Strength and muscle balance checks

A speed strength imbalance between two opposing muscle groups may be a limiting factor in the development of speed. Muscle balance testing to compare the strength of opposing muscle groups is important to prevent injury and guarantee maximum speed of muscle contraction and relaxation. Muscle imbalance can slow you down and result in injury.

Strength checks

Leg press to body weight ratio

Your leg strength to body weight ratio indicates how easily you can get and keep your body moving at high speeds. This ratio is important to speed improvements in short distances. A good ratio is 2.5:1 or a leg press score $2\frac{1}{2}$ times your body weight. If it is less than $2\frac{1}{2}$ then you should consider modifying the program to develop leg strength.

Leg strength test

The squat is considered the most functional leg strength test in predicting sprinting and jumping ability. Good 1RM (one-rep max) scores are:

- Male athletes 2 * 'Body Weight'
- Female athletes 1.5 * 'Body Weight'

Hamstring to Quadriceps Strength

For each leg record the 1RM for the leg curl and leg extension exercises. Divide your leg extension score by the leg curl score to find the ratio for each leg. For each leg the curl score should be at least 80% of your extension score. If the score is less than 80% then you need to devote more training attention to the hamstrings. To reduce the chance of injury the ratio should be at least 75%.

Bench Press

This is a test for upper body strength. The need for maximum upper body strength varies between sports and so it does not always need to be tested for. Good 1RM scores are:

- Male athletes 1.25 * 'Body Weight'
- Female athletes 0.8 * 'Body Weight'

Balance checks

For each of the following exercise the right and left limb 1RM scores should not differ by more than 10%.

- Hamstrings (leg extension)
- Quadriceps (leg curl)
- Arm Curl
- One arm military press
- Single leg press

The following table identifies reported values for joint agonist-antagonist ratios at slow isokinetic speeds.

Joint	Movement	Ratio
Ankle	Plantar flexion/dorsi flexion	3:1
Ankle	Inversion/eversion	1:1
Knee	Extension/flexion	3:2
Hip	Extension/flexion	1:1
Shoulder	Flexion/extension	2:3
Elbow	Flexion/extension	1:1
Lumbar	Flexion/extension	1:1

Where there is an imbalance then you need to devote more training attention to the muscle group of the weaker limb.

Brian Mackenzie

Module 6

Speed and agility

Introduction

There are certain numbers that will be remembered for a lifetime. Most sports enthusiasts will never forget their best 100 metre sprint time, and in the USA, no one forgets their personal best 40 yard sprint.

Why do athletes remember their personal best speed time all their lives? It is probably because speed is highly correlated with performance in most sports and speed has been shown in 2004 to predict athletic performance in US college football.

When should speed work be conducted?

It is important to remember that the improvement of running speed is a complex process which is controlled by the brain and nervous system. In order for a runner to move more quickly, the leg muscles of course have to contract more quickly, but the brain and nervous systems also have to learn to control these faster movements efficiently. If you maintain some form of speed training throughout the year, your muscles and nervous system do not lose the feel of moving fast and the brain will not have to re-learn the proper control patterns at a later date.

Overview of the articles in this section

- Phil Campbell explains the science and biomechanics behind the acceleration techniques that will increase your speed
- Gavin Hall explains his training session that makes speed training accessible and fun for all

- John Shepard explores tried and tested ways to fast forward your sporting performance

The articles in this section are applicable to most sports.

Acceleration techniques and speed development

There are certain numbers that will be remembered for a lifetime. Most sports enthusiasts will never forget their best 100 meter sprint time, and in the USA, no one forgets their personal best 40 yard sprint.

Why do athletes remember their personal best speed time all their lives? It is probably because speed is highly correlated with performance in most sports and speed has been shown in 2004 to predict athletic performance in US college football. For years, there were opinions about which tests were most valuable because no one really knew, which, if any of the tests would actually predict success for college athletes. A new study now provides the answers.

The researchers summarised their findings

The purpose of this investigation was to examine the relationship among six physical characteristics and three functional measures in college (US) football players. Data was gathered on 46 NCAA Division I college football players. The three response variables were 36.6 metres sprint (40 yards), 18.3 metres shuttle run, and vertical jump. The six regression variables were height, weight, percentage of body fat, hamstring length, bench press, and hang clean. A stepwise multiple regression analysis was performed to screen for variables that predict physical performance. Regression analysis revealed clear prediction models for the 36.6 metres (40 yards) sprint and 18.3 metres shuttle run. [1]

During recent years in the US, a system of selecting athletes for college and professional sports teams has evolved into several major physical tests involving speed, agility and strength given to athletes on the same day. These tests are called the ‘combines’ in the USA. Having a good day at the combines can produce on the spot scholarships from large universities, and it can mean literally millions of dollars in sign-on bonuses and salaries for athletes entering the professional ranks.

With the results of this new study, future ‘combines’ may focus on two acceleration tests. In the USA, the 40 yard sprint is king for many sports, except baseball, which uses the 60 yard distance required to run bases.

Big ticket items in teaching acceleration techniques

There are several acceleration techniques that can be taught in a few training sessions that will increase the speed of many athletes. Techniques like Ankle Dorsiflexion, Pocket/Chin Arm Swings, Acceleration Position, and the grand prize of speed training is the Valsalva Acceleration Technique.

Dorsiflexion

Most untrained athletes run with their toes pointed downward. While they may have fast leg turnover, but just like throwing a ball without using the wrist, the power is missing unless the foot is dorsiflexed (pointing up) and ready to fire off the ground. Dorsiflexion of the ankle simply means to raise the toes and, in essence, cock the foot before striking the ground. This action engages the ankle and the foot for additional power generation and this can mean additional stride length for the athlete. The Claw Drill and many of the skipping drills teach athletes to dorsiflex their feet.

Pocket/chin arm swings

Without exception, teaching proper arm mechanics for maximising running speed is the most difficult. Many athletes do not see themselves unless they are taped and they frequently gauge what they are doing with their arms based on their perception of how their arms feel during sprinting. In most cases, arms swings are incorrect and need repositioning.

'Pocket/Chin' is a good way of teaching arm mechanics and the Butt Bumpers drill is the best drill I have seen for teaching correct arm swing mechanics. Have your athletes sit on the ground with both legs straight in front (side-by-side) with arms locked at 90 degrees. In slow motion, have athletes swing one arm backward until the hand reaches the pocket, and one arm forward until the hand reaches chin level (approximately twelve inches away from the chin). This is the 'pocket/chin level' position.

Performing this drill in slow motion initially is a good idea until the coach sees that the athletes are getting the feeling of the arm positions. Move to half speed, then to full speed for three sets of five to 10 seconds. If performed correctly, it is easy to see why this drill is called butt bumpers.

In 1970 I was taught to run with arm swings pointed in a straight line forward. Now we know that this instruction slightly restricts the hips during running and thus, makes the athlete run slower. The arm swings should be pointed slightly toward the centre of the body in order to maximise the hips, which can increase stride length. Too much side-to-side will over rotate the hips and cause problems. If an athlete points the arms past centre of the body, this can make the feet push off the surface in a duck-footed style rather than push the athlete straight toward the target. When you see a problem with the feet, look to the arms first for correction as there may be an easy fix here.

Challenge them to perform pocket/chin drills with 'locked 90 degree arms' at home looking in the mirror, sideways and front ways.

Acceleration position

Due to the work of Brian Mackenzie, coaches are hearing about the importance of proprioception training for sports. This term becomes very important in teaching the acceleration position. The number one mistake made by athletes trying to run faster, is to stand up too soon in fly phase running without going through the 'drive phase', which is marked by an aggressive forward lean (at the ankles).

The description of an airplane taking off, low at first, but slowing raising upward with effort made to not jump up to quickly and bump the passengers heads, seems to be an understandable analogy for most athletes.

When performing the standard calf stretch, with one leg back and one forward, while leaning on a fence is a good way to reinforce the acceleration position – straight back, bent at the ankles.

Valsalva acceleration technique

A slower athlete can beat a faster athlete to the ball, to the hoop, to the tackle, to the touchdown, and to the finish line if the slower athlete is trained to hit the acceleration position (body straight, forward lean from the ankles) with arms pumping pocket-to-chin level and tactically using the Valsalva acceleration technique at precise points.

If you look up Valsalva manoeuvre on the internet, you will find that this describes briefly holding the breath. When applied properly for a brief burst of 2.5 seconds, this technique can be the greatest single producer of an instantaneous explosion in force, speed and strength known in science. Like many techniques, this one is so powerful that it can cause harm but it also delivers championship plays.

We all use the body's natural ability of increasing strength by unconsciously performing the Valsalva manoeuvre. My favourite analogy to explain this to athletes is to describe a situation where the athlete's mom hands the athlete a jar with a tight lid. Mom needs some extra strength to open the jar so she calls on the athlete for help. On first attempt, the lid is too tight for the athlete. On second attempt, the athlete increases the intensity and pushes hard with maximal effort.

If you will think about what the body does naturally in this situation, you will understand this valuable technique. The athlete tightens the abs, and holds the breath for two or three seconds as max effort is applied. This is the Valsalva manoeuvre.

The body increases blood pressure by additional 100 points very quickly with this natural action. Clearly, this is dangerous to older adults with potential for stokes and it can be dangerous to some young athletes. But this technique will assist an athlete to open the jar, lift more weight maximally, and to beat a faster athlete to the ball, goal or finish line.

An athlete can not perform a maximum lift while inhaling. Nor can an athlete quickly accelerate with maximum force while inhaling. The body is designed for the Valsalva manoeuvre and needs to be trained how and when to deploy the technique.

Valsalva acceleration strategy

Holding the breath too long can cause harm by making an athlete actually pass out. One occurrence is reported in the literature where this technique was responsible for bursting a tiny blood vessel in the eye of an athlete during heavy maximal lifting.

It is easy to observe that the Valsalva manoeuvre is frequently used safely as a natural function of the body to increase strength, but it is only held for two to three seconds naturally.

A 100 metre sprinter would have time to plan for four Valsalva acceleration techniques during the short ten second event, or a masters sprinter like me, may get in five before the finish. The miler may place the Valsalva acceleration technique in the race strategy 100 meters before the finish line to power that extra kick.

The 400 metre sprinter may want to deploy this technique during the four handoff zones during the single lap around the track. The baseball player may want to deploy this acceleration skill twice during the seven second trip to first base.

The football player may strategically use the Valsalva technique to break on the ball for a surprise steal. The applications for this acceleration technique are endless.

Conclusion

We have all seen the superstar athlete interviewed on television after making a game winning play.

'How did you make that great play?' asks the reporter.

'I knew that the game depended on it. I gave it everything I had, and I made the play' seems to be the frequent answer.

That is what we hear, but the athlete should have explained:

'I wanted to make the play so I made the extra effort to get into the acceleration position (with a straight body bent from the knees), pumped my arms pocket-to-chin level, and I positioned my shoulders lower to the ground than my competitor to drive my body forward toward the target, I took the extra energy necessary to apply the Valsalva technique to temporarily raise my blood pressure by an extra 100 points so I could get there faster then my competitor.'

Some athletes make great plays without knowing the science of acceleration, but what if all your athletes trained with these techniques throughout the season. Perhaps this technique explains why some teams that do not match the physical attributes of stronger teams, still find ways to win championship.

Perhaps the inferior team realised that they had to go deep inside, work hard, get into the acceleration position on every play, and use the Valsalva technique more to beat the superior team.

'Who wants the victory the most, will win this game' is what we say to the team. Perhaps we should train athletes to use this natural technique designed to assist the body to get into maximal effort so athletes will have the skills necessary to beat a faster athlete and not wait until it is the game winning play to deploy it.

I rest my case. Speed is a skill and skills can be improved.

Phil Campbell

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Inclusive speed for all to succeed

How many thousands of club runners run virtually every mile at the same pace? Who can blame them when 'speed session' can strike fear into the heart of all but the leanest racing snake? All too often then, many athletes undertake similar sessions, secretly wanting to go faster, but not having the confidence or knowledge to make a change.

To improve the athlete's running times we have to develop their speed. Running every mile at eight minute pace just makes the athlete really excellent at running eight-minute miles. Only by introducing some carefully managed overload can we sharpen up for speed.

I have developed a training session that makes speed training accessible and fun for all. It is designed for a mixed ability group to run on a road circuit of around eight miles. It is a low-tech approach, quite easy to coach, safe and lots of fun. Best of all, it works – 100% of the athletes that have undertaken this session with me once a week for twelve weeks have achieved a level of speed endurance they previously thought impossible. Come to think of it, I've achieved the same effect myself by coaching it!

Preparation

To coach this session you will need to create a road route of around eight miles designed around the speed interval lengths that you will read about below. Each interval should begin and end with a clear marker and consist of smooth, reasonably flat, well lit surfaces.

Paramount in the design of your route and interval sessions is safety (not a great idea to have a road junction in the middle of a speed interval!). Bear in mind the effect that the weather will have on your route. Will there be any risk of icing, water hazards, etc? Consider traffic noise – will you be able to make yourself heard at all times? Think about parked car hazards, bicycles, blind corners – you name it. Aim to make the route as risk free as possible.

The session itself – introduction:

As the coach you should:

1. Welcome the whole group
2. Introduce them to each other
3. Explain the purpose and structure of the session in detail
4. Explain the golden rules (detailed later in this article)
5. Guarantee improved speed for those who are prepared to stay for twelve weeks

Warm up:

Put the group into reverse speed order (fastest at the back). Bring any new members up to the front to run alongside you as you start the warm up. Keep the group tight, and keep the group slow, *ie* slower than the comfort level of the slowest runner. First mile very slow jogging including gentle mobilisation of the joints through striding, short-striding, etc. Second mile include some drills and strides to increase the heart rate and further warm the muscles.

One mile effort:

As you approach the first mile effort, brief the group on safety and on the specific aspect of technique that you want them to focus on for the session. Make sure that everyone knows where the end of the mile effort is and what to do when they get there, *eg* jog back slowly to fall in behind the slowest runner. Tell them to accelerate gradually for the first minute to reach the top speed that they can sustain for the rest of the mile.

Set your runners off (still in reverse speed order) for a maximal effort mile. First the nine minute milers, then the eight minute milers and so on. The aim is to try and have all runners finish the one mile effort at the same time.

Make sure that all runners don't just stop at the end of the mile. As they finish get the athletes to jog back and hook up behind the last runner completing the mile (because despite your best efforts, they will not all in fact finish at the same time!).

Re-organise the group into revised speed order again – making any adjustments based upon performance during the first effort. Keep everyone jogging along as you do this.

Half mile effort:

Keep the recovery period fairly short (a couple of minutes after the last runner finishes). Use this time to individually coach and motivate the slower runners. Re-emphasise the aspect of technique that you are working on and re-establish the reverse speed order you need. Check that nobody has any signs of injury – anyone who does simply knocks off the speed and jogs the rest of the way. Re-emphasise safety, clearly identify the half-mile end point and set your runners running (now the nine minute runner only gets a 30 second head start from the eight minute mile runner of course!)

Quarter mile effort:

Now it's time to really use those motivational skills. I'm not talking about screaming and shouting, just emphasising the positive a thousand times more than you normally do. Remember that all of your athletes should be finding this difficult. Tell them that it's OK to feel that way. Remind them that there is no shame in being slowest – check individually that nobody is in pain. Re-establish that reverse speed-order, adjusting again as required. Get everyone to summon up their deepest reserves, sort out your speed order again, halve your head start times again, three, two, one…GO!

Lamp post interval mile:

By now you should have about three miles to run. Tell that to the group – it's reassuring to those who are tired. After another short recovery jog, it's time to put those coaching skills to the test again.

This time, use lampposts (or similar landmarks) as individual effort markers for your group. Send them off individually, setting each a series of tasks to keep their effort level high over the next mile. Use your skills – the fastest runners might run six x 200 with jog-back-to the slowest-runner recoveries over this mile, whilst the slowest runners might make just two x 100 efforts without running back at all. Alter this section of the run each week to make it interesting. Consider 'lamppost ladders' (forward two, back one, forward three, back one, etc) or any other adjustment that you like – but be very cautious about making your tired athletes turn sharply – remember that their legs, joints, muscles and tendons will be tired.

During this section encourage everyone to keep the effort level high – remind them that the bulk of the speed work is done and that it will all be over in less than half an hour.

Re-group:

Re-group with only two miles to go, put yourself at the front with the slowest runners, put in a good five-minute slow jog recovery whilst you thank and encourage the group.

Tailor the last mile of the run to suit the needs of your group. Hardened and experienced athletes might want to put in some more speed whilst the slower runners jog back with you. This provides a great opportunity for you to get some feedback whilst further encouraging your slowest superstars.

Warm-down:

And so the journey ends – save for the warm down and stretching. I'm sure you have your own methodology – I simply emphasise bringing the heart rate down slowly before leading a carefully explained stretching session. Seek feedback, give positive feedback and end with a huge round of applause.

The four golden rules:

Forgive me for being over-prescriptive, but here are the actual words that I use to introduce this session – I'm sure that you will have your own rules and words, but these work for me:

- **Inclusive Access:** There is no minimum speed that you need for this session. If you think you are too fast for the group, then please leave. If you think you are too slow for this group, then please stay. Anyone criticising someone else for being too slow gets 'instant dismissal.' If you feel you are falling off the back of the group, don't worry, we will come back for you.
- **Safety:** Take responsibility for your own safety – if you are at the front of the group at any time, then think of those behind you – take the group past any obstacles and across any roads with the utmost care. Everyone must shout 'post' if they pass anything that others might run into. Shout loud, shout every time and don't assume that others have seen it.
- **Warm Up, Warm Down:** Coach is in front for the first two miles of the session every time without fail. And if you want to play, you have to stay to the end – including the warm down.
- **Work Hard:** When you run your speed efforts, accelerate gradually to your top speed for each distance. Push it all the way – hold nothing back and hold that maximal speed right through to the end of each interval.

Putting it all together:

Reading through the above, I am struck by the simplicity of this session and apologise to those who had hoped for something more scientific. I am amazed that it works so effectively. However, the results that I have seen from delivering this session consistently with real enthusiasm speak for themselves. Long established personal best times reduced by minutes, over all distances by athletes of all abilities. Many of these athletes had previously lacked enough confidence for track training, but others had trained on the track regularly. Pleasingly, this session has left us all injury-free for over six months.

I love coaching this session as it enables me to coach effectively whilst training at high intensity myself. It allows athletes of differing standards to work together inclusively and to access an ability that they had not previously dreamed of.

Gavin Hal

Speed, agility and quickness drills

Billy the Whiz, the Flying Scotsman and the Kansas Cannonball all have something in common apart from great nicknames: they all have, or had, great speed. In their human incarnations, 'the Whiz' is Jason Robinson, the staccato footed speed merchant who plays either wing or full back for England's rugby union side; Allan Wells is the Flying Scotsman, fast enough over 100m to win

Olympic gold in just over 10 seconds back in 1980; and Maurice Greene (the Kansas Cannonball) is, of course, the former World 100m record holder and current Olympic champion.

These athletes move, quite literally, in the blink of an eye. Like many of us in search of that most precious sporting commodity, speed, all have made use of a variety of techniques and equipment aids to sharpen them up. This article investigates some of these to help you gain some insight into how to fast forward your sporting performance.

SAQ drills

SAQ (an acronym for 'speed, agility and quickness') is the title of a system patented by a company called 'SAQ International', which works in the UK with top football teams like West Ham United and the Rugby Football Union, and internationally with the likes of the Miami Dolphins American Football team and the New South Wales Waratahs rugby team in Australia.

Jason ('the Whiz') Robinson has two of the fleetest feet seen on a rugby player and, although blessed with innate ability to dance rings around his opponents, he has also honed his agility through the use of such SAQ drills as the 'foot ladder'. This type of rope ladder, a key component of SAQ training, is placed flat on the playing surface in order to develop foot speed and improved foot ground contact.

There are numerous permutations of ways for athletes to step and run through the ladder, which can challenge the fast twitch fibres of even the fleetest athletes. 'One foot in, one foot out' (left, right, left into each rung) is not too difficult; 'two in, two out' (two feet one after the other into each gap) is more challenging; but backwards and sideways combinations definitely need to engage the brain as well as the feet. It is a bit like learning to waltz against the high speed rhythm of Garage music!

These drills, like many of the speed enhancing techniques mentioned in this article, are designed to optimise neuromuscular patterning and condition. Like any other physical attribute, speed can be trained and improved through repetition and overload. SAQ techniques never lose sight of this overall goal and the playing requirements of various sports. Depending on their emphasis, the drills are designed either to develop absolute speed and agility or to develop these attributes under the conditions of fatigue that players experience during a match.

Drills with a sport specific emphasis often shape up looking like an obstacle course, involving short swerves through cones, hopscotch, zig-zag runs, long swerves, two footed jumps over low hurdles, backwards running and turns through 360 degrees. Players are often required to perform even more sport specific tasks during the course of these workouts; for example, a rugby player might have to receive and pass the ball while running through the foot ladder.

The Frappier acceleration programme

The Frappier system is a more mechanised version of SAQ – think Terminator rather than Tarzan. It relies on high-tech kit like the 'Plyo-Press', the 'Multi-Hip', the 'Upper Body Implosion Unit' and the 'Super Treadmill'. The system is the brain child of American John Frappier, who began developing it in the 1980s. After gaining an MSc in sports science, Frappier spent a considerable time in Russia with the US junior gymnastics team and gained valuable insights into how the former Soviets trained for speed and power (a great deal of contemporary speed and power training theory is owed to the boffins behind the former Iron Curtain).

Back in the States, Frappier began working with top NFL (American Football) players and opened his first Acceleration Training Centre in 1986. Today there are more than 100 such centres, mostly in the United States but with one in the UK.

The Frappier system applies the principles of controlled overload to speed development. All athletes, whatever their sport, are put through a six week 'level one' programme, which identifies their individual strengths and weaknesses and introduces them to the programme's protocols, and particularly the use of the 'Super Treadmill'. Those in search of scintillating speed are progressed through a 12 level programme, while those seeking sustained speed endurance work through six levels. Both programmes use eight week training cycles, with three to four sessions a week. Speed workouts use the treadmill, while conditioning routines involve other items of specialist kit as well as more 'everyday' sports and speed conditioning drills.

After the six week introductory course, the Frappier system claims that you can expect, on average, a two-tenths-of-a-second improvement in 40 yards time and a two to four inch improvement in vertical jump ability.

The 28mph Super Treadmill is the key to the Frappier system, since it allows for the performance of flat and inclined running (up to 40%) under controlled conditions. The acceleration coach is able to stand alongside the athlete, offering verbal and uniquely physical support. A carefully placed hand to the lower back can 'spot' or support the sprinting athlete leading to the maintenance and development of biomechanically correct form.

The Plyo-Press is perhaps the most interesting of the other specialist pieces of speed enhancing equipment employed by the Frappier system. It combines weight based resistance training with plyometric training in one hit, allowing athletes to strengthen their muscles in a highly speed specific way. You select the appropriate weight from the weights stack in the same way that you would on a piece of standard fixed weight equipment, then lie on your back with the machine's pads behind your shoulders within a sort of track. From this position, you are able to generate the power to push yourself towards a footplate that you then 'react' against through your lower and upper legs to launch yourself back up the track

Conditioning this 'stretch/reflex' is perhaps the key to developing the power to move over a playing surface like a racehorse rather than a donkey. In sprinting, there are three stretch/reflex reactions, occurring at the ankle, knee and hip. If you can succeed in minimising the 'amortisation phase' (the gap between impact/stretch and power expression/contraction) you will be a faster, more powerful athlete. The Frappier system is designed to help you achieve this [1].

Uphill sprinting

The Frappier system, being true to its high tech principles, tends to eschew nature's hills for mechanised ones. But uphill sprinting, wherever it takes place, is a great way to develop speed. For best results you need a 30% gradient, which will optimally overload the ankle dorsiflexors and plantarflexors, the knee flexors (during the swing phase), the knee extensors and the hip extensors and flexors [2]. This degree of incline also results in greater range of motion at the hip and ankle, faster joint motions during push off and two to three times greater neuromuscular activity in the hip and knee extensors.

Downhill sprinting, elastic cord sprinting and the concept of 'over speed'

If uphill sprinting provides such a great speed enhancing opportunity, what about turning round and sprinting downhill? This activity will result in what is known as 'over speed' running. Greene is aptly nicknamed the Kansas Cannonball, and during his training it is more than likely that he will have used over speed downhill running and other over speed methods to reach speeds he would not normally be able to attain.

Other over speed devices include towing methods, running 'with the wind' and elasticised harnesses. These devices are essentially giant rubber bands that are attached around the waist. Tension is built up by pulling them out (you need a coach or another athlete to do this); when the harness is released, the athlete is pulled down the track beyond his or her normal sprint speed.

All over speed methods push or pull athletes to speeds they would not be able to achieve using their bodies alone. Whatever method is employed, it is crucial for athletes to 'fire' their muscles in order to achieve the super fast sprinting speed rather than being dragged to fast speeds. It is the same difference as falling or running down a hill. If you fall down, you may get to the bottom more quickly, but you will probably not remember how you did it. If you run down, on the other hand, you will be conscious of all your steps. For all over speed work you need to be conscious of your sprinting movements in order to maximise neuromuscular patterning.

Having tried most over speed methods myself, I have found that downhill running using a slight decline (10% or less) seemed to offer the greatest transference to my sprinting capability. Elasticised harnesses (read catapults), although great fun, were rather like roller coaster rides: very exhilarating and scary at the time but easily forgotten, with only marginal consequent improvement to my sprinting speeds. Downhill sprinting, however, enabled me to fire my own muscles, and because of this there was greater transferability to my on the flat sprinting.

The old Eastern Bloc countries were quick to realise the benefits of sprinting on various gradients. A trip to their former training facilities, such as Potsdam in East Germany, where they had constructed incline/decline sprint tracks, makes this perfectly clear. To achieve optimum speed transference, Eastern Bloc trainers would get their athletes to sprint uphill one week, on the flat the next and downhill the next.

Specific speed conditioners

1. The Powerbag

This is a relatively new item of speed and power enhancing kit, which is used by the England rugby team among other elite performers and has only very recently been launched to the wider fitness market. Powerbags are tubular padded sacks made from a rip stop vinyl, with webbing handles at shoulder width, which enable them to be easily carried, lifted and thrown.

Powerbags, which come in various weights, specifically address core stability, balance and the recruitment of the body's stabilising muscles – all key elements of speed and sport specific conditioning. In terms of speed development, they come into their own when conditioning explosive upper body power.

No matter how powerfully you might perform a traditional upper body resistance exercise, like the shoulder press, it is very likely that you will 'hold back' as you come to the end point of the press, simply because you will not be able to follow through as you would when throwing or pushing an object. With a Powerbag, you can safely condition this explosive, speedy response because you can throw it. The bag can even be caught by a partner and thrown back to develop upper body plyometric power in another way.

2. Speedballs

Allan Wells was a great advocate of the 'boxer's' speedball, believing that it enhanced his upper body speed and power. There is no doubt that it would have conditioned such a response (Wells being no slouch) but the drawback was that the firing pattern of the muscles of the upper arms and chest were developed in an opposite direction to that required for the sprinting action. However, the speedball does have its merits as a pre-conditioner and neuromuscular ‘sharpener’ and it is great to work out with to the theme from Rocky.

3. Foot-flexor devices

Foot-Flexor devices aim to secure the foot in a dorsiflexed position during sprint training and are attached around the sprint shoe to the ankle. The theory behind this form of sports bondage is that it encourages sprinters to run with their toes up rather than down, which contradicts the older coaching wisdom that sprinters should run high on their toes. Proponents of dorsiflexed sprinting believe that it maximises force return from the running surface, thus enhancing forward locomotion. A toe down position is seen to 'break' the sprinting motion because the lower limbs will yield as the feet strike the ground, no matter how strong the athlete's calf muscles. The devices themselves may be somewhat overrated, but the dorsi-flexed foot position is not; you really do get a feeling of greater power return from the track while running toes up, and the foot has to be 'coming back toward you' to optimise push off. However, concentrated toes up sprinting needs to be gradually introduced into an athlete's training programme to avoid injury.

If speed is your goal why not try out some of the above mentioned training methods and systems.

John Shepherd

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Module 7

Injury Prevention

Introduction

Like most athletes, you undoubtedly want to lower your chances of incurring an injury while participating in your favourite sport. Injuries decrease the amount of time you can spend in leisure activities, lower your fitness, downgrade competitive performance, and can lead to long term health problems.

One of the most common sites of injury, regardless of the sport, is the lower back region. There is a whole host of causes for lower back pain, *eg* in runners weak or inflexible hamstrings can often be the culprit. Poor posture is another common cause, so conditioning of the muscles that help to maintain solid posture should form part of the schedule of anyone who exercises regularly, whatever their discipline or sporting standard. A variety of muscle groups contribute to good posture and all require attention. Naturally the lower back muscles can do with strengthening. Work on the abdominal muscles is also important because it will complement work you do on the back region; it is dangerous to develop muscular imbalances by working on just one part of the body.

Overview of the articles in this section

- Karl Halliday explains that sharp pain you sometimes feel in the shins and what you can do to prevent it
- Joe Dunbar explains some gentle exercises which can help strengthen your most vulnerable parts – your lower back.
- Walt Reynolds explains how to come back from that most common of sports injuries – the sprained ankle

The articles in this section are applicable to most sports.

A pain in the shin

Traditionally, the term 'shin splints' was used to describe any prolonged or recurring pain between the knee and the ankle, especially in athletes. The pain came most often from an overuse injury, which is ironic since the term itself was overused. Nowadays we have a better understanding of sports injuries, so shin splints is a blanket term used to describe conditions of the lower limb such as compartment syndromes, stress fractures and medial tibial stress syndrome (MTSS). It is used most often interchangeably with the latter. But regardless of what you call the condition, what can you do to prevent it?

MTSS is a common overuse injury frequently occurring in weight-bearing sports in which the participant's feet are repeatedly striking the ground. Examples include middle- and long-distance running, jumping events, basketball, football and dancing. It is characterised by pain from the middle to distal end of the posteromedial border of the tibia (shinbone). Pain occurs during exercise and subsides with rest. At first it may be possible to train through the pain but this will only worsen the condition and eventually it may be impossible to walk without pain. At this point the injury has turned into a stress fracture.

With any injury the causative factors should be addressed first; this will avoid making the condition worse and reduce the likelihood of the injury recurring. Krivickas (1997) [1] indicated excessive pronation as the primary factor associated with MTSS. If the foot is allowed to pronate excessively, it alters the weight-bearing properties of the foot. It then becomes less efficient at absorbing shock and instead transmits the force of the impact to the tibia. This then places the athlete at greater risk of injury. During normal running, the soleus (the muscle in the lower part of the calf) works eccentrically to control the foot as it makes contact with the ground. If the foot is allowed to pronate excessively, the eccentric work performed by the soleus increases. This increases the tension of the soleus at its origin on the tibia, which in turn may result either in microdamage to the connective tissue that attaches the soleus to the tibia or in inflammation of the periosteum (surface layer of bone) at the point of attachment. Either of these will result in the pain commonly called shin splints.

How can you prevent shin splints?

If you have experienced this type of pain either during or after exercise, you first need to ask yourself whether you have changed anything recently, especially training methods or equipment. In many cases, it may only be a small change that makes the difference between a pain-free and a painful training session.

Noakes (1991) [2] believes that many novice runners who develop shin splints within the first three months of running can be cured by changing their running shoes. Look at the wear on the soles of your shoes – are they worn more on the inside, especially at the middle to front of the shoe? If so, you may be overpronating. You would be advised to get a pair of trainers that are suited to your feet. Some good running shops offer a computerised foot-scanning service that will help you find the appropriate trainers. An over-pronater needs a running shoe with good support, particularly along the medial longitudinal arch. If you have a different wear pattern, it is still wise to have your feet examined because a shoe that is too rigid can also cause injury

Avoid those training errors.

Perhaps the second most common cause of overuse injuries is training errors. What surface do you run on most? If you regularly train on hard, tortuous pavements, especially if there is a slight camber in the surface, then stop. Vary your running terrain. Running the same route week in week out, especially on hard, unyielding surfaces, uneven ground or too many hills can trigger MTSS. This may sound difficult to manage, but the key is variation. Vary where you run, how far and how fast you run and most important vary the surface you run on. For athletes such as dancers or gymnasts, who perform their activity indoors, training on a sprung floor will help to decrease the stress of repetitive impacts on the lower limbs.

Another training error is doing too much too soon. This can happen to the novice individual wanting to get fit or lose weight as well as to the experienced athlete early in the season or when returning from injury. The body will adapt to the demand you place on it but not as quickly as most people would like. You need to be patient and listen to your body. If you start to feel pain in the lower leg, then it may be an early sign of MTSS or other overuse injuries. A simple reduction in running mileage or training duration may be all that's needed to stop the pain.

An athlete with poor running mechanics will also have increased risk of lower-limb overuse injuries. A narrow running gait or feet that cross over when you run can increase foot pronation and thus stress to the tibia and soleus. In addition, too long a stride or pushing off too hard with the toes can increase stress on the lower limbs. Get a colleague to film you running and assess your running gait.

This is by no means an exhaustive inquiry into the causes of MTSS, but it does highlight the simple key factors that you can alter easily to reduce the likelihood of injury or help in recovery. Other factors that have been pinpointed as likely to increase the chances of MTSS include menstrual abnormalities, low-calcium diet, muscle imbalances, inflexibility, hereditary factors, cold weather, insufficient warm-up and skeletal structural abnormalities.

Karl Halliday

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Corrective action for poor posture

Whether you aim to run a marathon, perform step aerobics, scrummage for Harlequins, or cycle from London to Brighton, you should not neglect a proper conditioning routine as part of your training if you want to achieve muscular balance and avoid injury. The best prepared sportsmen and women tend to have a comprehensive routine, often involving muscles that are not directly connected with their particular activity.

One of the most common sites of injury, regardless of the sport, is the lower-back region. There is a whole host of causes for lower back pain, *eg* in runners weak or inflexible hamstrings can often be the culprit. Poor posture is another common cause, so conditioning of the muscles that help to maintain solid posture should form part of the schedule of anyone who exercises regularly, whatever their discipline or sporting standard.

A variety of muscle groups contribute to good posture and all require attention. Naturally the lower back muscles need strengthening and work on the abdominal muscles is also important as it will complement work undertaken on the back region. It is dangerous to develop muscular imbalances by working on just one side of the body. The contribution of the gluteal and hamstring muscles should not be overlooked when considering sound posture and preventing injury to the back region.

It makes sense, therefore, to develop a session that will work on all these areas and give the right level of conditioning for injury prevention. As a number of different exercises are used in the following training session, it is possible to construct a mini-circuit. The idea is not to undertake ‘circuit training’, with athletes working eyeballs-out in a gym, trying to pump out as many repetitions of each exercise in as short a time as possible. Far from it, if you adopt that attitude to this particular session, you'll be risking injury rather than helping to prevent it.

Your emphasis here should be on completing the exercises in a controlled manner so that there is no loss of form and no unnecessary tension throughout the body. For this reason the session is known as the ‘No-rush Circuit’. There is no stopwatch involved and no target heart rate. The intention is to gently condition the muscles rather than to boost cardio-respiratory fitness.

Six exercises are involved and you simply move from one to the next to complete the circuit. If you incorporate such a session, once or twice a week, into your exercise schedule, it will prove valuable, whatever your sport or activity.

The six exercises

1. The sit-ups (abdominal development):

Here you lie on your back with your legs bent, feet flat on the floor. Rest your hands on your thighs and sit up until your hands touch your knees. Note that you do not sit all the way up, but simply slide up and move back down in a controlled fashion.

2. Back arches

Lie on your front with your legs crossed so that your feet remain firmly anchored to the floor. Raise your upper body off the floor, taking care to keep your head in a neutral position (neither looking to the sky nor staring at the ground). Hold this position for two seconds and then lower yourself down again in a controlled fashion. It is easiest to keep your arms resting on your back, but as you get better at the exercise you can put them in the 'hands up' position or straight out in front to add to the resistance. You may progress to holding a weight.

3. Speed cramps

These work on a different part of the abdominal muscle group and are performed a little faster. Lying on your back, keep your legs in the air, bent at the knee. Your hands can rest lightly on the side of your head and NOT interlocked behind the neck. Simply raise your body up to bring your elbows to your knees and go straight back down.

4. Gluteals and hamstrings

Start in the same position as for the sit-up, except have your hands lying by your side. From here, raise your hips and one leg and hold for a second before lowering. Repeat the exercise with the other leg.

5. Short sit-up

Start in the same position as the first exercise but keep your hands in the same position as the speed cramp. Raise your body so that your torso is at a 30 to 40 degree angle to the floor. If you come up any higher, the work is concentrated more on the hip flexors than the abdominals. Hold this position for two seconds before coming back down slowly.

6. Back extensions

Sit with legs bent, feet flat on the floor. Position your hands on the floor behind you to take some of the weight. Raise your body off the floor so that your torso is parallel with the floor. Hold and lower.

Keep a sense of balance

The first time you do this circuit, start with 10 reps of each exercise and complete just one circuit. As with any training programme you need progression, so you can add to this in subsequent sessions. Begin by increasing the number of reps you do within each circuit. Do not expect to be out of breath at the end. Remember that the idea is to tone the relevant muscles to condition your body well.

Keeping a sense of balance is essential for all your training. If you do other types of strengthening work, think carefully about the muscles that you are training and whether the session is appropriate. For example, in most gyms around the country there are many pieces of equipment to help strengthen your quads but few to address the hamstrings. The danger is that the quads will be far stronger than the hamstrings and this can cause all sorts of injury problems. The answer here is to work hard on the hamstring muscles, either with leg curls or, if the machinery is not available, get a partner to hold your ankles as you kneel. Then gently rock forward as far as you can and let your hamstrings pull you back. You can perform a number of reps of this exercise to help redress the balance. Similarly, if you work out in the gym regularly and give a lot of attention to the biceps, make sure you don't neglect the triceps and cause another imbalance.

Joe Dunbar

Recover from a sprained ankle with a balance board

Whether you are a rugby enthusiast, a football player, a cricketer, a runner, or just a ‘weekend warrior’, you have no doubt been troubled at some time by that most common sports injury – the sprained ankle. Sprained ankles are ‘double trouble’: they can be extremely painful, and they often curtail training or competing at key times of the year. Worst of all, even after you have ‘recovered’ from an ankle sprain, your ankle is temporarily weaker than normal, and thus you are at a higher risk of sustaining another sprain – or even a more serious ankle injury. What should you do to re-build your ankle after a sprain?

Surprisingly enough, the answer is to use a balance board. Balance-board work can improve your overall coordination and thus take excessive strain off your ankles and help you move more efficiently. A balance board can also increase the active strength of the muscles in your ankles, as well as your feet and legs, dramatically lowering your risk of injury. In addition, balance-board routines can upgrade the mobility and flexibility of your ankles (as well as your feet, shins, and calves), further decreasing injury risk and leading to more powerful push-offs and longer strides whenever you move vigorously during your sporting activity. While you strengthen your ankles, you will also give your performances a boost.

Not just ankle sprains

Best of all, balance-board routines are good for other injuries, too. Although balance boards are not especially popular among athletes, balance-board training has been used for decades by sports-medicine specialists to rehabilitate and treat a wide range of injuries to the foot, ankle, shin, calf, knee, hip, and trunk. These injuries include (in addition to ankle sprains) Achilles tendinitis, Achilles-tendon ruptures (post-surgery), shin splints, calf strains, ACL tears and ruptures, hamstring maladies, and low-back problems. Boards are also utilised frequently by patients who have undergone hip-replacement surgery, as well as by individuals who have gone under the knife to repair a troublesome back.

Even though balance boards have historically been used primarily in a therapeutic setting, they have recently become more popular with serious athletes as a training tool. As balance boards have squeezed their way into the training arena, the line between balance-board rehabilitation therapy and balance-board training has become increasingly fuzzy, as therapists and coaches have begun to borrow techniques and methods from each other. Among athletes who use boards, the current thinking is, “If they are good for rehabilitation from injury, they are probably good for prevention of injury, too, and thus might help me train more consistently". Among physical therapists and other sports-medicine specialists, the thought is, "If athletes are using balance boards in certain ways, those techniques should also be good for patients who need to restore functional strength".

For individuals who engage in a sport that requires a fair amount of running, a primary area of concern – from both an injury-prevention and training standpoint – would be the structures of the foot, ankle, and lower part of the leg (including the muscles, tendons, ligaments, bones, and cartilage in those areas). These structures are under constant stress during running and undergo considerable (and repeated) loading even during short runs, with a force equal to two and a-half to three times one's body weight passing through the body parts with each step. Athletes have become increasingly aware that they need to shore up the strength of the lower parts of their legs, and they are also beginning to realise that if they can strengthen and more effectively coordinate the actions of their feet, ankles, shins, and calves, they will be able to develop more explosive and powerful push-offs and thus longer strides, leading to potential gains in performance.

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 (12-16 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 degrees 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 one-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 20 degrees 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, coordination, 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 coordination 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

Using a square rocker board placed on a wooden floor or firm carpet carry out the four exercises described above 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 six 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 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 coordination, 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 practised 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

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 coordination 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 degrees 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 eight reps, and then shift over to the other leg. After a brief rest, complete eight more reps with each leg. As your coordination and strength improve over time, you may increase the number of reps and sets.

'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 'bells which produce significant fatigue after about 15 reps. 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 three or four sets as your strength and coordination improve.

As if that were not bad enough!

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 it for 15 seconds, and 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 five 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 coordination. You will find it to be 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 10 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 coordination and technique; do not worry about racking up lots of reps. 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 coordination 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 coordination, 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 coordination 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 gives his/her okay. Use the balance board frequently during training to lower the risk of future injury – and to enhance your performances.

Walt Reynolds

Module 8

Psychology

Introduction

At the top level it is not your physical or technical expertise, which separates you from the competition but your mental toughness. To be outstanding you have to hold your nerve, perform under the most intense pressure, and consistently turn it on even when you do not feel at your best.

The increased stress of competitions can cause athletes to react both physically and mentally in a manner which can negatively affect their performance abilities. They may become tense, their heart rates race, they break into a cold sweat, they worry about the outcome of the competition, they find it hard to concentrate on the task in hand.

Given that mental strength is so vital, then why is it so neglected in training routines? If you are one of those athletes who spend all your training time on technique and fitness while paying no attention to your mental side, you are doing yourself a serious disservice. We know from countless studies that mental skills are acquirable and you can, with practice, learn to perform mentally. You can improve your confidence, concentration, motivation and anxiety levels if you chose to.

This has led coaches to take an increasing interest in the field of sport psychology and in particular in the area of competitive anxiety. That interest has focused on techniques which athletes can use in the competitive situation to maintain control and optimise their performance. Once learned, these techniques allow the athlete to relax and to focus his/her attention in a positive manner on the task of preparing for and participating in competition.

Overview of the articles in this section

- Lee Crust examines the preparatory conditions that are powerfully linked to optimal performance and make success more likely
- Adam Vile explains how Doris assists Johnny Wilkinson to stay focused on the Rugby pitch and how we might acquire similar mental skills
- Lee Crust offers an in depth analysis of a Basket Ball Coach's problem related to his team's motion offence patterns

The articles in this section are applicable to most sports.

For peak experiences in sport, you need to go with the flow

One of the most perplexing characteristics of athletic performance is the fluctuation that can occur between one day and the next. What seemed like a rhythmical, easy, flowing performance one day can appear forced, awkward and disjointed the next.

Of course, there are many interacting factors that help to account for such fluctuations within individuals. What seems clear is that human beings are incredibly complex, which is why attempts to predict behavioural outcomes based on either physiological or psychological characteristics have often proved unsuccessful.

But, although common experience tells us that we cannot produce our best performances every time we compete, what if science could uncover a set of preparatory conditions that were powerfully linked to optimal performance and made success more likely? Sport psychologists have recently been working hard trying to do just that.

Surprisingly, this area of study has tended to be overlooked by researchers as the predominant focus has been on overcoming negative psychological states, like anxiety. Psychologists regularly work with athletes to alleviate such problems by means of applied techniques, such as imagery or goal-setting. Much less is known, however, about the positive subjective experiences (states of consciousness) that have been variously described as peak experiences, optimal experiences, peak performance or 'flow'. In this article these concepts are considered as conceptually similar (although some researchers define each separately) since strong correlations between them have been demonstrated in a number of past studies [1].

There is a range of possible experiences an athlete might encounter on a continuum from disorder, such as anxiety, to harmony, such as a state of flow. In a team situation this continuum could relate to cohesion or lack of it.

What is flow?

One of the most important aspects of my role as an applied sport psychologist is talking to athletes about their experiences in order to gain an insight into their thought patterns and typical ways of functioning. This is a prerequisite to establishing the best ways for athletes to prepare for competitions and intervening effectively to combat any negative processes, such as stress. As part of this approach, I ask the athletes to describe their best and worst performances in as much detail as possible, including the thoughts, feelings and perceptions associated with these specific events. When describing their optimal performances, athletes across a wide range of sports and levels of performance tend to give remarkably similar responses. (If you are an athlete, you might like to think about this yourself; if you are a coach, you might like to use this exercise with the athletes on your team.)

Tennis players, for example, have described being completely absorbed in their matches, anticipating things before they happen and feeling as if they had all the time in the world to hit their shots, while retaining a sense of automatic responding and control. One player described himself as being so focused that the tennis ball seemed more like the size of a football.

A runner reflecting on a long-distance training run talked about feeling comfortable, easy and so immersed in the activity that she lost all sense of time. A footballer talked of feeling so attuned to the game that he was completely unaware of any spectators and felt himself moving automatically (on auto-pilot) and responding without thinking. A golfer recalled a fluid, easy swing and the feeling that he was in complete control and could land the ball wherever he pleased. In recalling these events, their association with positive emotions and enjoyment is easily apparent.

An altered state with eight defining characteristics

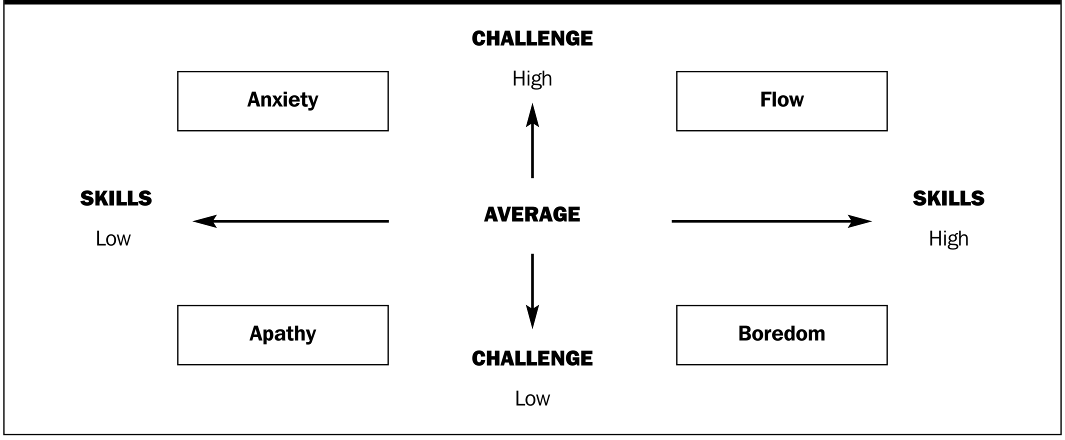
Some authors have referred to flow as an altered state of consciousness to reflect attention changes, but it is far from being a common mode of functioning, and research with elite performers seems to confirm that it is achieved infrequently [2]. The subjective examples mentioned above fit neatly with research definitions of flow, which is said to have the following eight characteristics [1]:

1. perceived challenge-skill balance
2. merging of action and awareness
3. clearly-defined goals and feedback
4. total focus
5. sense of control
6. loss of self-consciousness
7. time distortions
8. intrinsically rewarding experiences

To take the first characteristic first, by comparison with negative states such as anxiety – where there is a perceived imbalance between the demands of the situation and the athlete's ability to cope – flow seems to be related to a perceived balance between challenge and ability [3]. Additionally, flow has been said to be particularly likely to occur in situations of above-average challenge and skill.

This link between skills and challenge is illustrated in Figure 1, below. However, recent research suggests this model may be an over-simplification, since flow is not always present in high challenge/high skill situations. Indeed, in certain circumstances flow has been shown to occur in situations of low challenge/high perceived skill, which were predicted to facilitate boredom.

Figure 1 – A flow model [4]



When describing the experience of flow, athletes tend to talk of things just happening automatically when they are thinking of nothing in particular. It is as if they become one with the activity. This kind of state seems most likely to occur when athletes have clear goals that allow for feedback regarding progress towards objectives. Total immersion in an activity is apparently most common when an individual knows and understands the goals for a given activity. This seems to reflect 'order' and certainty rather than 'disorder' in consciousness.

One of the experiences that clearly characterises flow is a sense of total concentration on task-relevant cues, with little if any processing of irrelevant information. Distractions are minimised, and athletes typically report a narrowing of focus. At the same time, they are aware of a sense of total control of even the most difficult situations, with little concern about how others perceive them.

Finally, people have reported time distortions associated with flow, with perceptions of time either speeded up or slowed down. For distance runners, time may seem to pass exceptionally quickly during a training run as they become totally immersed in and focused on the activity. By contrast, racket sports players may feel they have an abundance of time in which to select, organise and elicit an appropriate response. Ultimately, however, the end product of a flow experience appears to be the sensation of 'being on a high'.

The enjoyment associated with flow is thought to be related to 'intrinsic' motivation – the desire to perform an activity for its own sake. This is very different from 'extrinsic' motivation, which is linked with external rewards, such as prize money and trophies. However, this does not mean that flow experiences cannot be attained while pursuing an external reward.

Although a satisfactory research base has been established, it is clear that our understanding of 'flow' is still in its infancy. Of greatest interest to athletes is the research on the circumstances most likely to facilitate flow. In two research studies [2] [5] elite athletes have suggested that they can make flow happen, although conscious efforts to switch it on like a light are likely to prove disappointing.

It is probably most useful to focus on factors that have been identified as necessary precursors to flow, as follows:

- positive mental attitude
- confidence in meeting the challenge
- mental plans
- physical preparedness
- task goal-orientation
- optimal environmental and situational conditions
- positive team cohesion
- high motivation
- enjoyment
- maintaining appropriate focus

The first two factors, positive mental attitude and confidence, would appear to be consistent with theoretical work, since it has been suggested that flow will occur in situations where perceived skills match challenge. An athlete would need to be confident in his or her abilities to meet the challenge in order to experience flow. Mental plans and physical preparedness have previously been linked to optimal performance in Olympic athletes [6]. Good preparation is likely to remove uncertainty and allow total focus to be directed towards what needs to be done in order to achieve success.

The importance of goal-orientations

One of the most innovative studies in this area focused on the role of goal-orientations and how differences were potentially linked to experiences of flow. Goal-orientations are all about what success means to individuals and how they evaluate their achievements. Success may be judged in terms of either quality of performance, irrespective of opponents and objective result (task-orientation), or comparison with others (ego-orientation). For example, a marathon runner may judge success as finishing in the top 50 (comparison with others/ego) or breaking two-and-a-half hours (quality/task). It is clear which is the preferred goal orientation, since you may beat your PB but still finish outside the top 50 simply because you cannot control how other people run.

Not surprisingly, task-orientation has been shown to be related to higher levels of intrinsic motivation and persistence, while ego-orientation is more likely to be linked with anxiety (a barrier to flow).

Do external rewards threaten or even replace intrinsic motivation?

Since elite-level sport is highly competitive, involves competitive goal orientations and can shift the emphasis away from the activity towards the external rewards, some researchers have speculated that flow is more likely to be achieved by lower-level participants. Previous research has shown that extrinsic rewards such as prize money may reduce intrinsic motivation or even replace it, as the reason for participation changes and is perceived to be controlled by the reward. With the relationship between flow and intrinsic motivation well established, anything that reduces the enjoyment and sense of self-actualisation may also reduce the chance of achieving flow. However, even though 81% of elite performers reported experiencing flow infrequently [7], at this stage it is still unclear whether their non-elite counterparts experience it more often.

Other recent work has suggested that some individuals are more likely to experience flow than others because of pre-dispositional (personality) factors such as goal-orientation, perceived sporting ability, competitive trait anxiety and intrinsic motivation. Environmental factors might also need to be taken into consideration: a recent study of 1,231 aerobic dancers found that ratings of the motivational qualities of music during classes were significantly related to ratings of flow [8]. Music rated as more motivational may enhance enjoyment, and in activities where music is matched to movement participants are more likely to become immersed in the activity and experience positive effect. It is evident that more research is needed before firm conclusions can be reached about the most effective flow facilitators.

What about factors that might prevent flow? It is just as important to remove known obstacles to flow as it is to promote it through known facilitators. Factors associated with preventing flow have been identified as follows:

- physical problems such as injuries
- mistakes by self or team-mates
- distraction and loss of concentration
- negative mental attitude
- low confidence
- low intrinsic motivation

In conclusion, flow is closely related to peak performance and optimal experiences in sport and exercise settings and, as such, must be seen as a Holy Grail for athletes, coaches and sport psychologists alike.

It is obvious that flow does not just happen, since certain precursors have been noted. And it would be unrealistic to expect to achieve flow during every performance, since it appears to depend on interactions between a combination of mental, physical and environmental factors. At this stage, it is impossible to predict with certainty when or if we will achieve such a state, and in many ways this is part of the intrinsic challenge of sport. We can, however, contrive to maximise our chances of experiencing this enviable state by preparing both mentally and physically to meet the challenges of competition and training.

Undoubtedly, flow is a difficult phenomenon to measure and cannot easily be quantified by psychometric techniques. However, the development of measures such as the Flow State Scale-2 (FSS-2) offer the promise of future investigations and perhaps the establishment of more consistent routes towards peak experience and performance in sport.

Finally, it is important to bear in mind what factors are most strongly related to flow. By embracing the challenges of sport and enjoying the journey towards our goals, the intrinsic rewards we gain are likely to lead us automatically in the direction of more positive experiences.

Lee Crust

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Mental Models – Noticing distinctions

There is no denying it; some people are just much better at some things than others. No matter how much effort you put in, no matter how much practice, there just seems to be an insurmountable gap between them and us. In general if someone is a professional sportsperson they have the luxury of time and resources that amateurs do not have, but even then there are vast differences between the skills even of world-class athletes. It cannot just be practice, although this clearly has a major impact, perhaps it is talent? Yet some may argue that it is talent that gets you noticed, and gives you the opportunity. You have to somehow turn that talent into enhanced skill. So what is the difference that makes the difference?

Consistency

One of the key attributes of world-class athletes is consistency, the ability to perform at a top level of skill in every situation. Milton Erickson, a psychiatrist who was a pioneer in the use of Hypnotherapeutic methods in sport, worked with a number of world-class athletes (including the US Olympic Rifle squad and the shot putter Donald Lawrence). In one story relating to a tournament golfer (Rosen 1989 [7]) Erickson is asked to assist in improving the golfer's consistency across all holes throughout a round. He seemed to always play the first hole perfectly, and then deteriorate. The question, for Erickson was: if you can play the first hole perfectly, then can you do as well on the next? He put the golfer in a trance and told him "You will play only the first hole, that is all you will remember, and you will be alone on the golf course". The golfer, needless to say, played an excellent round in his next tournament.

This is one of the things that set Johnny Wilkinson above his peers, consistency. He is feared by opposing teams for his ability to turn pressure into points, and he is able to do it under the most stressful conditions. How does he do this? In fact his approach is not too dissimilar from that taken by Erickson. You only have to watch him prepare for a kick; he uses the same ritual every time "He places the ball carefully, the same way that he has so many times before. Shutting out the cheers and jeers of the crowd, he stands up, and walks just the right amount of paces backwards. Then takes a single sidestep. But he is not yet ready. Standing with his feet a shoulder width apart, he clasps his hands in front of himself, staring at them for what seems like an age. Finally looking towards the posts, tilting slightly upwards, he pulls his head back just a little, as if the target somehow magnifies in his vision. He focuses, and there he sees her, sitting right in the middle, in the crowd, between the posts. Then he feels it; he knows that he is ready. And the rest is history". (Vile and Biggs (in Press) p.44 [8])

By following this series of steps, the same steps each time, he is able to get himself in the zone and shut himself away from all the pressure and noise. He has a single focus of attention, the process of kicking a rugby ball over the bar and between the posts, he is alone and it seems that for him, this is the only kick that matters. If you have a chance to watch him, you may also notice the defocusing of his eyes, and the flattening of his face, as he stares at his hands, the way looks up at the posts, bringing them closer in his mind, visualising the ball going up, and then down between them.

However Johnny attributes his success to one fact above all, that he is able to visualise a woman sitting in the crowd behind the posts, directly in-between them. He has named her Doris. He aims for Doris, and invariably collects the three points on offer. Essentially, Johnny Wilkinson hallucinates during his kicking process. Hallucination, along with a number of other phenomena that Johnny exhibits – single focus of attention, defocusing of the eyes, disassociation – are signs of trance. When he is at his most accurate, most elegant and most efficient, Johnny is in a brief, specifically directed trance.

If we wish to replicate Johnny's consistency we not only have to practise constantly (even on Christmas day apparently), modelling his style and specific movements, we have to understand his mental processes as well. As Annett 1995 [1] suggests, "The key to cognitive motor learning lies in elucidating the way in which learned skills are represented in memory". Often it is the mental processes that are the difference that makes the difference. These processes are skills, and skills can be learnt.

Acquiring mental skills

The good news is that just like their physical counterparts, mental skills can be developed and perfected. The acquisition of physical skills can be thought of as a three-phase process (Fitts and Posner 1967 [3]): Cognitive (focussing on the nature of the task); Associative (develops proprioception – learning to feel if our movements are correct); Autonomous (making this an unconscious process). Mental skills can be thought of as developing in the same way.

Skill acquisition essentially begins in the cognitive stage with the process of modelling the skill required. This is a straightforward matter when this skill is physical and can be observed and taught. In particular the use of videotapes and computer software can assist is establishing the finer nuances, which perhaps the performer did not even know about. Yet when the skill has mental components, or is a purely mental skill, you can only achieve so much by observation, the way to really understand the breakdown of the strategy is to ask. And of course you have to ask the right questions.

Bandler 1982 [2] tells of a time that he was asked to assist a Baseball player raise his game. Not knowing much about baseball, he watched a lot of videos of the top hitters and observed a pattern of behaviour that could only be attributed to mental processes. He interviewed a number of them and found out that as the ball was thrown towards them they were using a mental process of slowing down the ball, and making it much bigger. This made it, for them, easier to hit. Now of course the ball did not actually slow down or increase in size, and equally they did not go through this process consciously. But this process did exist and it did seem to be the difference between the top hitters and the player that wanted to improve. In real terms, these players were exhibiting the signs of trance: time distortion and hallucination, being two indicators. So Bandler taught this player to go into trance, and make the ball bigger, and go slower. He connected this to standing on the plate. The player improved his game and became a top hitter.

The difference that makes the difference

Not all mental strategies are connected with trance, but many are. Hypnosis has, for a long time, been utilised in improving sports performance, and research is now catching up (Ligget 2000 [5]). Alternative models (Robazza 1994 [6]) are suggesting that (alert) hypnosis should be induced before or during performance. The suggestion, which I fully support and want to argue here, is that self-hypnosis should be part of the skill set of an athlete.

Practically, of course, we are not all hypnotists and inducing trance does require special skill and training. Anyone can learn self hypnosis, and we have seen that some sportsmen use alert trance as part of their mental strategy for success. We need not focus on trance in our modelling of mental processes however, as it will come as a by-product, if we get it right. The key elements of such modelling concerns the way in which we represent skills internally.

We may make the assumption that experience is stored internally in the three main sense systems (Visual, Auditory, Kinaesthetic), and that by modelling and replicating this structure, we can have access to the same experiences as someone else. In this way we have more chance of developing the same mental skills. Understanding how someone represents skills internally then is essentially a case of asking the following two questions repeatedly:

- What do you See, Hear and Feel, inside, when you are about to (perform whatever physical skill)?
- What do you do then?

These questions address two aspects of internal strategy, the key representations associated with the skill, and the order in which things happen.

For example Johnny sees Doris, he hears nothing (shutting out the crowd) and he feels that it is right (I would be interested in asking him how that feeling starts and where it moves to). Then he kicks. For some athletes it may be that having a thumping soundtrack playing in their head gives them just that extra push (after all many of us listen to music as we run), but it may not start until they hear the gun or get a specific feeling in their stomach of excitement. If these strategies are successful, then they constitute part of the whole that makes up a specific skill, and such mental strategies may tip a performer into the world-class arena.

The key to modelling the mental structure and process is to notice finer and finer distinctions. For example, when Johnny sees Doris, is she in focus or out of focus, does he wait until she is in focus and then he knows that it is the right time? Without asking, we will not know, but if we can find a successful performer in our sport, and understand the order, structure and distinctions in their mental strategy, then we will have a model of the psychological underpinning of whatever skill we are working on.

By way of example you may like to try the following exercise on yourself, or with your athletes. Pick a time in the past when you were highly motivated. Go back and see what you saw, hear what you heard, feel what you felt. Imagine you have a control panel in which you can adjust the representation. It has the following controls: Volume, Brightness, Contrast, and Focus. Adjust them up and down until you feel totally motivated and utterly compelled. Write down the numbers on each control knob. Now think of something that you do not want to do (the washing up always gets me) and make a representation of you doing it. Set all the controls to those of your most compelling motivation. How does that make you feel?

The key to modelling internal process is to understand not only at the general level of what it is that the expert sees, hears and feels internally, but also the fine distinctions that they make in these representations. It may be that you can take these basic building blocks and subtly modify the distinctions to suit your own representations, improving perhaps at the micro level, whilst adopting at the macro level the winning strategy.

Towards autonomous installation

Having broken the mental processes of the expert on a specific skill down into a number of representations in a specific order we then need to install it in ourselves and in our athletes. This is the process of Association. It is important to remember the aim of our modelling, to learn a whole skill. So the mental processes that we have elicited must be connected with the physical aspects of the skill, and should go hand in hand with the practice of that skill. During coaching sessions the mental and the physical aspects must be practiced and seen as two sides of the same skill.

We do have an additional advantage in the learning of mental skills: they can be practiced and refined almost anywhere. Even on the bus. There is enormous value in repetition (of course assuming that the correct components are repeated), and mental skills can be repeated far more and much more quickly. There is a view (Bandler 1982 [2]) that the brain learns quickly, not slowly (how long, for example, does it take you to learn a phobia?). We can take advantage of this by repeating and practicing the skill mentally at a much faster rate than we would perform it in practice.

By constant repetition, these mental skills and strategies will become unconsciously installed. Additionally in moving to the autonomous stage, we can benefit from hypnosis, which can quickly install processes directly in the unconscious. Accelerated learning works in this way, and many sportsmen can see immediate benefits in their game after just one or two sessions of hypnosis (Holdevici 1989 [4]).

Understanding mental processes is just as relevant for the occasional squash player as for an international sportsman. My challenge to you is to go out, and notice distinctions. Start with the way you represent success yourself, and replicate that the next time you are competing.

Turn up the brightness, pump up the volume and if you want to, play to win!!

Dr. Adam Vile

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Help me give my team the will to win

As a basketball coach and member of the Australian Coaches Association, I am currently coaching a Division 1 women's team in Geraldton, Western Australia, with athletes ranging from 15 to 34 years of age. I have needed to take most of these players back to basics, which is fine, as the athletes have picked up on them. I have been endeavouring to teach them motion offence with three different opening patterns, and man-to-man defence with three different presentations: full court, half court and from a zone.

While running through these systems in a 3-on-0 to 3-on-3 and then 5-on-0 to 5-on-2 to 5-on-5, they are doing okay. The problem comes when they are put into a game situation, when they may run these systems two or three times then revert back to old habits, when it is very difficult to get them back on track.

With the season due to start, I am concerned that my message is not getting across. I have tried positive reinforcement with the group as a whole and individually. I have spoken to the players one-on-one and also had them complete a questionnaire, which revealed they were all thinking positively about themselves in both their private and sporting lives. They are all keen to improve and learn more about the game.

I believe that I have the utmost respect of all the players, which has been demonstrated by them approaching me for help and extra coaching in areas of concern.

I have been coaching this team twice a week for the past six weeks in two-hourly training sessions. Can you make any suggestions that will help me to improve my coaching?

David Rowe

Sport psychologist Lee Crust replies...

The manifest problem is one of 'transfer'. In this case it seems that the players are experiencing difficulties in transferring offensive strategies from practice to game situations. Although my usual approach would involve speaking to the coach and team members personally in order to establish a rapport and to ask any relevant follow-up questions as necessary (possibly to identify any hidden reasons for this problem), I will try to offer some practical advice based on the information you have supplied.

First, it would appear that your relationships with team members are productive and the performers seem to have high motivation and positive thought patterns. However, my own experience has taught me to investigate communications as a first source of any team-related problems. When relationships between coach and team members are good, it can often be difficult to communicate negative feelings such as displeasure, frustration (on the part of a coach) or doubts (on the part of players) for fear of damaging positive channels of communication. It is important to establish whether the team members are aware of your task requirements and realise they are not following your desired strategy. By clearly communicating thoughts and feelings a coach can reduce the risk of misunderstandings.

As coaches, we often assume that players understand and can connect with what we are asking them to do. As an active coach in a variety of different sports, I am often amazed at how commonly misunderstandings occur. Many times I have worked on techniques and simple strategies in isolated situations before introducing progressions and building up to full game situations, only to find that many players do not actually make the 'cognitive transition' from drills to game situations. Many experienced coaches I know have reported similar responses. The point is that players do not 'automatically' make a smooth transition: a simple model of teaching can help to demonstrate what I mean.

In teaching a new skill, the usual sequence of events would be as follows:

- to instruct – often using verbal guidance
- to demonstrate – usually visually
- to allow the learners to practise, and finally
- to confirm the amount of learning that has taken place

This final stage is a feedback process, which in this case appears to reveal that the learners have not fully comprehended the concepts you were trying to get across. Communication and confidence are both key components of progressing from this point, and it may be necessary to re-evaluate set goals.

Although the use of positive reinforcement is an important tool for allowing 'behavioural shaping' to occur, the withdrawal of praise or use of constructive criticism can also help to get your message across to players. Thorndike's law of effect suggests that using positive reinforcement strengthens the likelihood that people will respond in the same way when presented with the same choices in future – implying that behaviour is controlled by its consequences. However, the converse is also true, and by following behaviour you wish to 'stamp out' with criticism or negative consequences you theoretically reduce the chance of it happening again. Thus, you might consider this negative approach as an option when the players revert back to old ways of responding. But be careful, because it can have drawbacks!

Using both positive and negative techniques together can be a powerful way to promote behavioural modification, as the withdrawal of previous criticism as a response to more appropriate behaviour can also act as a positive re-enforcer. However, when being critical always try to inform the individual or team why their choice of response was sub-optimal. You might start by asking a player or your whole team why they opted to run an alternative offensive play. This might help you gain insight into their thought patterns (especially if they are not confident in the new plays).

Although part of the problem appears to be with communication and understanding, an additional factor could be your players' current stages of learning. Experienced players will undoubtedly have developed fixed 'automatic' behavioural patterns and ways of responding that are difficult to change. Psychologists refer to the weakening, tapering off and eventual disappearance of a learned response as extinction. This occurs when re-enforcers are removed, but it must be said that even highly-skilled and motivated performers find the process of behavioural change difficult. If these players have previously learned habitual responses for given situations, the natural tendency is to revert back to old habits (a comfort zone) – especially in stressful or demanding situations. This regression is usually reinforced if an early set-back occurs when running the new behavioural pattern, so shaking confidence. This may be what is happening in your situation, since you have indicated that the players initially run the desired offensive strategies before reverting to alternative approaches.

There are many potential reasons for this regression: first, the time scale required for modifying behaviour varies according to the strength of previous habits. Although you have been coaching the team for six weeks, this is still a relatively short period of time in which to expect a perfect transition from practice to competition, if the requirements are complex and depend on an integrated team response. It appears that you have made some progress already and your players might simply require further practice and 'over-learning' to strengthen stimulus-response bonds and build confidence.

Another common cause of reversion to old behaviours is to do with situation-specific confidence or self-efficacy, which can occur even when athletes are generally confident. For example, a basketball player may be confident in her defensive skills, passing and even lay-up scoring but lack self-efficacy in free-throw shooting after missing a number of recent attempts. Albert Bandura's theory suggests that self-efficacy is the primary mediator of behavioural change: essentially the adoption and persistence of behaviours are thought to be determined by expectations about one's skills and capabilities to successfully perform the desired behaviour in specific situations – practice or competition [1]. Expectations about the outcomes are also important, in that athletes may be internally weighing up the possible outcome of putting a new behaviour into practice in a challenging situation.

When athletes lack match confidence

In other words, your athletes may lack confidence in their abilities to successfully execute the new behaviours. That is not to say they doubt the importance or relevance of these strategies, but they doubt their own or the team's ability to successfully execute your wishes in pressure situations. You suggest the players are doing 'satisfactorily' in practice, but this may not be enough to give them full confidence when implementing strategies in competition. In this case, it appears they have come to terms with only part of the triple-threat offence, so it is likely that they lack the confidence to reproduce it in matches.

Often doubts experienced by a single player can spread to others, creating a spiral that triggers the search for a comfort zone (promotion of team security) and culminates in actions that the players are confident in producing (old habits). There may be a case here for running simpler patterns, if appropriate, or incorporating some kind of simulation into practice to make things more realistic, and so build confidence. Simulation is important, since task mastery and performance accomplishments in the particular situation have been shown to be the most dependable sources of self-efficacy [2].

I read with interest the recent article by Raphael Brandon on team cohesion and the approach taken by England Football Team manager Sven Goran Eriksson [5].

Eriksson transformed his team of also-rans into a coherent formation, who became serious contenders for the World Cup (narrowly losing to eventual winners Brazil) by employing psychological strategies. In the process he worked extensively with internationally respected psychology consultant Willi Railo, whose philosophy of 'daring to lose to win' is based on findings that successful performers tend to be risk-takers with a low fear of failure.

Fear of failure is a psychological state that afflicts many sports performers and is characterised by conservative thinking and limited risk-taking behaviours that often serve to inhibit performance. Fear of failure was considered to be evident within the England team when Eriksson began to implement Railo's ideas to create a 'shared mental model'. This involves individuals instinctively reading a situation and arriving at a common solution. Such an approach is, of course, the very essence of teamwork and the ultimate goal of any team coach. It is also very difficult to achieve.

The model revolves around players who grasp the ideas of the coach most readily and share a similar vision. These individuals can grasp the coach's ideas, helping to break down barriers and resistance to change in the mind-sets of other team members. This so-called 'cultural architect' can spread the coach's vision and bring the team closer to mental harmony. Such cultural architects are not common but can usually be identified relatively quickly among a squad of players. In the England football team, it is commonly assumed that David Beckham is one such individual, although two others are thought to exist.

Another approach I would recommend for promoting new habitual responses within your basketball team is the use of imagery. Imagery can be incorporated into regular training sessions and promoted as a way of training during physical rest periods. It can be used to run through strategies and tactics and has been shown to boost self-efficacy [3].

I would suggest talking through the importance of the new strategy with your players and highlighting a particularly well-executed example from a practice or game situation (you might even videotape such an example). In a distraction-free zone, have the players recall the sequence of events (including positive feelings as well as visual, auditory and kinaesthetic information) by talking them through their responses in as much detail as possible. Identify the roles of each player within the sequence and set them some mental homework to recall this sequence frequently – before going to sleep is often a good time.

Mental training does not have to be a burden on athletes' time, since 10 minutes a day is likely to be beneficial. It is the quality of the images and the positive outcomes that are important. You might need to discuss the details of an imagery program with a psychologist or, alternatively, refer to a practical book called *In Pursuit of Excellence*, by Terry Orlick, which also provides examples of simulation exercises [4].

You can train smarter by practising using your mind

The use of imagery can allow further practice away from the court and, providing the images are vivid and controllable, the brain will respond in much the same way as it would to 'real' stimuli. The brain interprets imagined stimuli very literally, and this can lead an individual to become so familiar with the response that further confidence is developed, as the desired response has apparently been achieved many times. Given time, these players should start to respond in a more automatic way to the new stimulus as each begins to predict the actions of others. There really is no substitute for practice, but you can train smarter by practising using your mind. Be patient, though, because changing established behaviour can be a difficult and time-consuming process.

You might also consider trying to strengthen the stimulus/response bond in your players by establishing a 'trigger' for the desired sequence of events. This could simply be a call from a team member, a movement, or a more elaborate connection that precipitates the new behaviour. Using a 'cultural architect', if you can identify one, to trigger a response would be a smart move – as their efforts and visions can influence others.

Changing the athletes' thought patterns by a technique called 'cognitive restructuring' could also be helpful. Cognitions that are likely to inhibit the desired behaviour by initiating a negative response are highlighted and reframed into more positive alternatives. The presentation of key phrases that instruct the players might be used as self-talk strategies, with repeated affirmations or instructions regularly practiced by the squad. This type of programming can have a real impact on athletes' belief systems. You might need a psychologist's help with this. However, in a team environment imagery is likely to be equally – if not more – positively received.

I hope these suggestions have opened up a few new avenues for you to explore within the often complex dynamics of team situations. What initially seems a very easily identifiable problem can actually have many potential causes, and I am afraid the solutions depend upon many possible interactions.

Lee Crust

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Module 9

Ergogenic Aids

Introduction

With better dope testing methods and hence the possibilities of detection and life ban from the sport, athletes and coaches are looking for legal ways to improve performance and/or hasten recovery. The various ways by which performance can be improved are known as Ergogenic Aids.

Ergogenic Aids may:

- directly influence the physiological capacity of a particular body system thereby improving performance
- remove psychological constraints which impact performance
- increase the speed of recovery from training and competition

Ergogenic Aids fall into the following categories:

- Mechanical Aids, *eg* Heart Rate Monitors
- Pharmacological Aids, *eg* Supplements
- Physiological Aids, *eg* Sports Massage
- Nutritional Aids, *eg* Carbohydrate Loading
- Psychological Aids, *eg* Hypnosis

Overview of the articles in this section

- Tony Palidin examines the benefits of Creatine phosphate as an ergogenic aid
- Ken Grace examines the use and benefits of the heart rate monitor
- Alun Williams reviews the research conducted on the use of Sodium Bicarbonate to improve anaerobic performance
- Ron Maughan examines the risks associated with taking supplements

The articles in this section are applicable to most sports.

This ergogenic aid allows the athlete to train harder for longer.

Adenosine triphosphate (ATP) is a substance stored in one's muscles, yielding instant energy through the cleaving of the phosphate bond from an adenosine molecule. Stored ATP is therefore the only fuel capable of generating 100% muscle contraction. Once ATP is exhausted, however, other fuels dominate the energy supply, all of which are converted to ATP before they are used (carbohydrates, fats, proteins and Creatine phosphate).

The average person stores enough free ATP for four to five seconds of maximum muscular contraction: enough to do one squat, throw a javelin or run 50 metres. Because it is the only way that one can ever put a maximum load on one's muscles, muscle contractions fuelled by stored ATP is unquestionably the most effective way of building strength. However, this is also the most dangerous way to train as maximal muscle contractions carry the greatest risk of ligament, tendon and connective tissue damage.

Following four to five seconds of maximal exercise, a substance known as Creatine phosphate (CP) becomes the dominant energy yielder, permitting near maximal muscle contractions for another five to six seconds. This ATP/CP interaction is anaerobic and uses no glycogen, glucose, fatty acids or amino acids. Maximal exercise extended past the five second ATP barrier into the CP system of up to 12 seconds (ATP+CP) obviously becomes much safer as the amount of micro trauma is significantly less than ATP alone.

As an adenosine molecule is cleaved off one of its three phosphate molecules for the energy stored in the bond (becoming an adenosine diphosphate [ADP] molecule), a CP molecule immediately jumps into action, donating its phosphate molecule to replenish the ADP molecule back to an ATP, leaving a free floating Creatine molecule. Following a muscle contraction most of the free Creatine and phosphate join up to regenerate CP. This process however, requires oxygen, which means that anaerobic exercise has to be stopped to allow this to happen. Following maximal exercise, this process takes about five minutes for 90% CP regeneration. This therefore means that for optimal strength gains, the athlete should ideally wait five minutes between sets before doing the next set – a long time!

This is where Creatine supplementation fits in as it facilitates a full load of Creatine phosphate in every muscle. It allows the athlete to train harder for longer. The oral form of Creatine monohydrate is the most digestible. The amount of intake depends on how much muscle there is to fill and how much exercise the person does.

In order for an athlete to warrant taking Creatine, there should be a minimum training load of five or more days a week and training maximal resistance at a high intensity. Therefore in order to reap any benefit from Creatine whatsoever, the athlete has to train…HARD.

A recommended dose of Creatine for hard training athletes is approximately 0.1g/kg lean mass (lean mass is FAT FREE mass, not total body weight). Doses should be divided into smaller mini-doses that should be taken before, during and after exercise). It is essential that doses should be taken with a sugar drink (such as a fruit juice) and after a meal.

Doses should not be taken on an ongoing basis as there is evidence of Creatine supplementation interfering with the body's own metabolism over the long term. Over dosing should also be avoided at all costs as excess Creatine has been shown to interfere with the regulation of the kidneys resulting in water retention.

Young athletes have no need for Creatine as the only time benefit is gained with Creatine is during maximal resistance training. Young athletes have no need for this kind of training and therefore no need for Creatine.

Tony Palidin

Reference

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The heart monitor as a tool for training

The first wireless heart rate monitor (HRM) was introduced in 1983 and since then many improvements have been made, *eg*

- Coded transmission process (from chest strap to watch) to reduce interference with other HRMs
- Ability to capture large amounts of data
- Functions to aid with training, *eg* high and low ranges for setting training zones
- Ability to download the captured data onto a computer and then analyse with special software

The use of an HRM to set exercise intensity is based on sound physiological principals – as the work increases, oxygen consumption (VO_2) and heart rate increases in a linear relationship until near maximal intensities. Heart rate is easier to measure than oxygen consumption and the relationship between them has been established, however, there is one critical component – knowing your maximum heart rate.

VO_2 max

They are a good tool for seeing how stress affects the body because as workload goes up heart rate goes up. While heart monitors are not good for predicting, or measuring VO_2 max they are a great tool for monitoring and measuring aerobic fitness levels below maximum effort.

Maximum oxygen uptake, or VO_2 max, is the body's highest ability to use oxygen at the cell level. Scientists and physiologists are constantly studying maximum oxygen uptake and give us numbers in relation to bodyweight of what is good, what is average and what is poor. The higher the VO_2 max the better the individual is at processing oxygen. So obviously, world class endurance athletes tend to score really high and sedentary people, who have under developed aerobic systems, score really low. As VO_2 max improves so does the general health and wellness of the individual.

Most coaches, and physical education teachers, do not have access to physiology labs so how do you get an idea of a person's VO_2 max? It turns out that VO_2 max is very close to the average pace that a person can cover in an all out 10 minute run or bike ride (If they have properly trained to cover the distance.) To establish a VO_2 max have the rested athlete perform a 10 minute time trial. Use their average pace to figure out what is VO_2 max pace. A recent two mile or 3,000 meter race also provides a place to start when trying to establish VO_2 max pace. For example an athlete running a 10:00 two mile would have a VO_2 max pace equal to around 5:00/mile. At the same time, if this is an all out effort, you could use the heart monitor to establish a maximum heart rate.

A 10 minute all out effort is too much to ask from a new athlete. In fact it would probably scare them away! With new athletes, and aerobically underdeveloped athletes, we can estimate their maximum heart rate and use these numbers to set up a beginning aerobic training plan at 65% of VO_2 max pace.

Maximum heart rate

First we need to estimate the new person's maximum heart rate. Ideally we would measure it… And at a much later date we can, but for the time being I suggest you use the Miller formula outlined in *How to Use Heart Rate to Quantify Fitness Training Intensity* by McGuire.

The Miller formula is:
Maximum Heart Rate = 217 – (0.85 x Age)

Let us use a 27-year-old male: MHR = 217 – (0.85 x 27) = 194 bpm
75% max heart rate is approximately equal to 65% VO_2 max.
So, 194 bpm x 0.75 = 145 bpm to be training at 65% VO_2 max pace.

These same calculations can be used to figure percentages up to around 90% of VO_2 max pace. Beyond 90% of VO_2 max pace the heart rate monitor becomes less reliable and the focus now should shift to actually timing and controlling the pace of the repetitions. In between efforts that are run above 90% VO_2 max pace the heart monitor is a great tool for measuring recovery heart rate. By monitoring the recovery rate we can measure positive changes in fitness.

Heart monitors can be used with highly developed athletes. If VO_2 max pace has been determined, the heart rate monitor can be use to build a heart rate training pace chart. For example, a 10 minute 2 miler has a VO_2 max pace equal to roughly 5 minutes per mile. A 90% VO_2 max run for a 10:00 2 mile would be equivalent to around 5:33/mile pace. By having the athlete run at 5:33/mile pace we can establish a heart rate that corresponds to this effort. In the example below the athlete achieved a heart rate of 175 bpm while running at 90% VO_2 max pace.

A run at 65% of VO_2 max for the athlete below elicits a heart rate of around 147 bpm.

Name	:	Joe Runner
VO_2 Max Pace	:	5:00/mile
Max Heart Rate	:	196
90% VO_2 Max Pace	:	5:33/mile
Heart Rate @ 90% VO_2 Max Pace	:	175 bpm
65% VO_2 Max Pace	:	7:41/mile
Heart Rate @ 65% VO_2 Max Pace	:	147

When VO_2 max pace, and the corresponding heart rates, have been established the coach and athlete can develop a chart with a variety of percentages to meet their training needs.

Heart monitors provide a method to measure effort, or intensity, more accurately then just asking the athlete how they feel. An athlete planning to do a recovery run away from the track at 65% VO_2 maximum pace usually has to guess at the pace or go by how he feels. With many highly motivated athletes this recovery run turns into another tough training session and the objective for the workout is lost. The heart monitor is a great tool for the over ambitious athlete.

Heart monitors provide an inexpensive way to measure improvements in fitness levels, below maximum effort, and recovery. During a meso-cycle of training (four to six weeks) an athlete probably repeats a particular workout a number of times. By recording the heart rate at end of each work repetition and then again at the end of the recovery the coach and athlete can gain insight into how effective the training process is. The key to measuring intensity away from a controlled environment, like the track, is being able to monitor effort using heart rate. Recording resting heart can alert both coach and athlete to effects the training cycle has on the heart.

Heart rate monitors are a tool.

Like all tools they can be misused, or the information they provide can be misinterpreted. It is important for the coach and athlete to remember that heart rate is only one measure of what is going on. Heart rates can be affected by a number of extraneous variables like heat, humidity and dehydration. The key is to use the heart rate monitor in conjunction with other training markers consistently measuring, comparing, and evaluating heart rate during training and performance.

Ken Grace

For more information check out these books:

1. John L. Parker Jr., 'Heart Rate Training for the Complete Idiot'
2. Ed Burke, 'Precision Heart Rate Training'
3. Sally Edwards, 'Heart Rate Guide Book to Heart Rate Training'

Sodium Bicarbonate may help you if your events last between one and seven minutes

Bicarbonate has been researched by sports scientists for some time, producing inconsistent results, though some studies have suggested it has great potential for enhancing anaerobic performance. Perhaps the one major confounding factor is the relatively common side effect of stomach problems. I will come back to this later, but, first, what is the rationale behind the use of bicarbonate by athletes?

Underlying theory

Energy production via anaerobic glycolysis, which is particularly important for events lasting between 30 seconds and 15 minutes, increases the acidity inside the muscle cells and very soon after does the same to the blood. It is this increase in acidity within the muscle cells that is a major factor in producing fatigue in such events. If there was some way to reduce the acidity within the muscle cells, one could theoretically delay fatigue and thus continue exercising at a very high intensity for longer. Sodium bicarbonate is an alkalising agent and therefore reduces the acidity of the blood (known as a buffering action), but cannot enter the muscle cells to reduce the acidity there. However, by buffering acidity in the blood, bicarbonate may be able to draw more of the acid produced within the muscle cells out into the blood and thus reduce the level of acidity within the muscle cells themselves. This could delay the onset of fatigue.

Who might benefit?

The specific athletes who might stand to benefit from bicarbonate supplementation will typically compete in events that last between one and seven minutes, *ie* 400m to 1500m running, 100m to 400m swimming, most rowing competitions, and many teams' sports with their repeated nature of high intensity exercise which stresses the anaerobic glycolysis system significantly and produces a lot of acidity.

Research is saying it works

Bird and colleagues (*Journal of Sports Sciences*, 1995, vol. 13, no.5: pp399-403) persuaded 12 middle and long distance runners to compete in a total of six 1500m races. The three different conditions were: after bicarbonate ingestion, after placebo ingestion and after ingestion of neither of these. The bicarbonate ingestion trial produced race times (about 4:14 minutes) mainly between three and five seconds faster than the other two conditions.

Hausswirth and colleagues (*European Journal of Applied Physiology and occupational Physiology*, 1995, vol. 71, no. 4: pp362-368) found that eight subjects were able to improve local muscle endurance of the quadriceps during a sustained contraction at 35% of maximal force after ingestion of sodium citrate (sodium citrate raises blood bicarbonate by a similar amount as sodium bicarbonate itself).

Callier and colleagues (*Cinesiologie*, 1994, vol. 33: pp45-50) had 12 male subjects perform five one-minute bouts of cycling with two-minute rest intervals at an intensity equivalent to 100% VO_2 max after placebo or citrate ingestion. The fifth bout of cycling was in fact longer than one minute and continued until exhaustion. Citrate ingestion delayed fatigue in the fifth exercise period, adding an average of 20 seconds to exercise capacity that was determined largely by anaerobic function.

Some research suggests it does not work.

Cox and Jenkins (*Journal of Sports Sciences*, 1994, vol. 12: 469-475) used eight moderately active male subjects to evaluate the effects of sodium citrate ingestion on repeated 60 second sprints on a cycle ergometer. Despite changes in blood bicarbonate and lactate measures which suggested that the supplementation was working correctly, performance (work done cycling) was no different between supplementation and placebo trials.

Kozak, Collins and colleagues (*Medicine and Science in Sports and Exercise*, 1994, vol. 26, no. 12: pp1510-1515) also found no significant improvement in performance, although their raw data did suggest some improvement which may have been significant if a larger sample size had been used. After ingestion of sodium bicarbonate or a placebo, seven competitive female cyclists performed intermittent exercise of one minute at 95% VO_2 max, the next minute at just 60 watts, until exhaustion after an average of nine bouts at each intensity. Once again, blood measures of bicarbonate and 'buffering capacity' had increased but had not been reflected sufficiently in the all important performance measure.

Stomach irritation

One possible reason why there has been such conflicting research both recently and earlier is the fact that many subjects suffer short term stomach complaints after ingesting sodium bicarbonate. These may take the form of pain, cramping, diarrhoea or a feeling of being bloated. So it is hardly surprising that individuals who feel nauseous do not go out and perform better than they normally do. Thus, some potential benefits of supplementation may be neutralised by the effects of nausea in some subjects, and when the effects are averaged in the scientific trials, ergogenic effects are hidden.

A practical approach

Before using either bicarbonate or citrate supplements, it is wise to check with the governing body of your sport that the substance is not contrary to doping regulations. All major organisations at present do not prohibit such use, and this is unlikely to change, but it makes sense to check.

The most important practical point is the need to experiment with the supplement during training. Typically, an 800m runner, for example, may perform a time trial (this should really be with competition to ensure maximum effort) on a particular day after a couple of days of light training. A further couple of days later, after only more light training, the athlete can repeat the time trial in a similar environment after bicarbonate supplementation.

The exact protocol would be to ingest 0.3g of sodium bicarbonate per kg body weight approximately one to two hours before the time trial. That is, for a 66 kg runner, consume 20g of sodium carbonate (about four teaspoons) and, yes, the commonly found bicarbonate of soda is exactly the substance needed. This experimenting, if repeated several times, should reveal whether bicarbonate supplementation is likely to produce any benefit and whether the athlete concerned is susceptible to stomach upsets.

It is likely that large individual differences do exist as far as response to supplementation is concerned. It has been suggested that the more highly trained athletes are less likely to benefit from it because their body's natural buffering systems are already so well developed, but so far this is just speculation. It has also been shown that sprinters build up more acidity within their muscles than endurance runners in response to the same exercise, and so may be more likely to benefit from the buffering effect. From the scientific research, it appears that the size of the dose is quite important, and that taking only 0.2g per kg is less likely to be beneficial than 0.3g per kg, although no evidence exists suggesting that an even greater dose is better still.

As for the side effects, the athlete who suffers must try to eliminate them. Drinking up to a litre of water with the dose is often effective and should be carried out as standard. Breaking up the bicarbonate dose into, say, four equal portions taken over the course of an hour may also help. Finally, some researchers have reported that using citrate instead of bicarbonate reduces the incidence of stomach irritation, although the report referred to earlier by Cox and Jenkins unfortunately observed that nausea was experienced by seven out of the eight subjects following citrate consumption, and that five of those seven subjects vomited during exercise. Only one subject vomited during exercise after taking the placebo.

Buffering at altitude?

From the scientific evidence available, it appears that bicarbonate or citrate supplementation does improve buffering capacity, and thus clearly has the potential to enhance anaerobic performance.

However, the responses are likely to vary between individuals, as will the susceptibility to side effects. For a competitive athlete in an appropriate sport, experimenting at a personal level should establish whether the supplement is beneficial. As for the scientists, they need to establish whether supplementation is particularly suited to certain types of events more than others.

In addition, the potential of regular bicarbonate supplementation to increase training load as well as one off performance capability deserves some research attention, as does its potential for athletes who train or compete at altitude, where natural buffering capacity is reduced.

Alun Williams

When the price for 'harmless' tablets is just too high

At a time when world standards in sport are moving to ever higher levels, and training programmes are becoming ever more demanding, the athlete who wants to make it to the top and stay there must explore all possible means of securing an advantage. Nutrition offers one obvious way to get ahead.

A varied diet, consumed in quantities sufficient to meet the energy needs of the athlete in training, should provide all the essential nutrients in adequate amounts. But not all athletes eat a varied diet, and total food intake may at times be restricted, which can lead to deficiencies of some nutrients. Because these deficiencies may be difficult to detect in their early stages, athletes are often tempted to take individual nutrients in a concentrated form as a precaution. And an enormous multinational industry has grown up to cater for this demand.

However, athletes should take supplements only after balancing the potential rewards against the very real risks. Although vitamin and mineral supplements are perceived as harmless, and the daily multivitamin is regarded as an insurance policy, supplements are not always benign.

Routine iron supplementation, for example, can do more harm than good, and the risk of toxicity is very real. It has been estimated that, in industrialised countries, twice as many men suffer from iron overload due to excessive use of supplements than from iron deficiency.

But there are other risks associated with taking supplements – risks that are less physically threatening but may be more difficult to reverse.

More exotic supplements, many of which have names and promotional material that suggest an anabolic action, have become a prominent feature on the shelves of sports nutrition stores in the last decade or two. Some of these products make extravagant claims about building bigger, stronger and faster muscles, repairing the damage caused by hard training, resisting infections and illnesses, and preventing chronic fatigue. They usually come with fancy price tags, but for the athlete who is training to the limits no price seems too high.

This may be true in a strictly financial sense but, if we are to believe some of our top athletes, they have paid a far higher price in recent years. Being labelled a drug cheat is something no athlete wants and no innocent athlete deserves. Every effort must be made to ensure that athletes who use illegal drugs to enhance performance are caught and punished but, at the same time, the innocent must be protected.

This brings us to the thorny issue of Nandrolone in sport. Nandrolone is the popular name for the anabolic androgenic steroid more properly known as 19 nortestosterone. Many different androgenic anabolic steroids, including nandrolone and testosterone itself, have been used by athletes over the years, and well established measures are in place to detect abuse.

The apparent spate of nandrolone cases in British athletics over the last couple of years has cast a shadow over the sport as well as the individuals involved. Dougie Walker, Linford Christie and Mark Richardson are among the top athletes from various countries who have produced positive tests for nandrolone, although Walker continues to protest his innocence even after completing the two year suspension from competition that effectively ended his career, and the others also vigorously deny any wrongdoing.

This problem is not unique, either to athletics or the UK. Football, boxing, cycling, rugby, weightlifting and many other sports have seen similar cases. Nonetheless, UK Athletics has taken the lead in investigating the possible reasons for the positives.

Were the athletes cheating?

The problem was approached with an open mind, and all possibilities were considered, including the possibility of deliberate and systematic cheating by the athletes concerned. A review of the positive cases within athletics revealed that all of the athletes had reported using a range of dietary supplements, mostly from the same supplier.

A study carried out at Aberdeen University showed that administration of these supplements to athletes and to healthy volunteers training at a more modest level resulted in some positive tests. And those who tested positive recorded concentrations of 19 norandrosterone (the nandrolone metabolite whose presence is taken as evidence of nandrolone in the system) of up to about 30ng/ml of urine: anything above 2ng/ml and 5ng/ml for females counts as a positive.

Initial analysis of the supplements taken by the athletes and volunteers did not detect nandrolone or any other related steroids that could explain these positive tests. The International Athletic Federation (IAF) did not accept these results, which were, in truth, difficult to explain. But, because of the time pressures, it was not possible for the researchers to test a large number of supplements or a large number of athletes before presenting these data to the IAF.

However, when the analysis of some of the dietary supplements was repeated, using an improved method developed by the IOC accredited laboratory in Cologne, the Aberdeen and Cologne laboratories both found tiny amounts of a number of different steroids in several of these supplements. The amounts of steroids, although sufficient to play havoc with the careers of these athletes, were far too small to have any beneficial effects on performance. The supplements did not say on the label that they contained any banned substances and the athletes involved believed them to be suitable for use.

At about the same time as these results were coming out of Aberdeen, similar findings were reported from lOC accredited drug testing laboratories in Germany, Canada and the USA. In Italy, two athletes tested positive after taking iron tablets, and nandrolone precursors were later found to be present in some of the tablets. In Germany, nandrolone has been found in creatine powder sold to athletes.

Strict liability still applies

There is now a considerable weight of evidence to show that not all dietary supplements can be regarded as safe, even when the label or promotional material says they are. As before, however, the principle of strict liability applies (meaning that the athlete is responsible for whatever is in his or her body, irrespective of how it got there) and athletes who test positive in these circumstances are technically guilty.

Dietary supplements are not evaluated by regulatory agencies, and inaccurate labelling of ingredients is known to be a problem. Most supplements, it has to be said, will not cause problems for the athlete, and most companies that manufacture and supply these supplements are anxious to ensure the welfare of their customers. Nonetheless, the supplements reported to have been used by athletes who gave positive tests, backed up by the Aberdeen research, were all apparently innocuous substances, which should not have resulted in positive tests, even in the high doses used by some of these athletes. Until the picture is clarified, the only safe course for prudent athletes would seem to be to avoid anything that cannot be absolutely trusted.

An authoritative paper published in the scientific literature in November 2000 [1] provided some of the first solid evidence of steroid contamination of dietary supplements.

This study reported the results of analysis of three legitimate dietary supplements – Chrysin, Tribulus Terrestris and Guarana – none of which declared on the label that they contained steroids or might reasonably have been expected to do so. The researchers found nandrolone, testosterone and other steroids in these supplements. When they were fed to healthy volunteers, they gave positive nandrolone urine tests, with urinary concentrations of up to 360ng/ml (remember, the threshold for a positive test is 2ng/ml for men and 5ng/ml for women).

The Cologne laboratory followed up with a much bigger study of 634 different product samples from 215 different suppliers in 13 countries around the world [2]. The samples were analysed for the presence of steroid hormones and their precursors, and 94 supplements (14.8% of the total) were shown definitely to contain prohibited substances. In another 66 samples (10.4% of the total), the analysis was inconclusive, but steroids may have been present. Substantial numbers of positive tests were obtained from products bought in The Netherlands (26% of 31 products tested), Austria (23%), the USA (19%), UK (also 19%) and elsewhere.

The supplements which produced positive results have not been identified, but they included vitamins and minerals, protein supplements, creatine and many others. It was interesting to note that 21% of products from companies selling prohormones (substances converted in the body into active hormones) tested positive, while only 10% of samples from companies that did not sell prohormones were positive.

The lOC accredited laboratory in Vienna has repeated the Cologne study, albeit with a smaller number (54) of supplements. They found that 12 of these (22%) contained prohibited steroids, almost the same proportion as the Cologne lab found for supplements bought in Austria. Unlike the German results, the identities of the companies and their products have been published on the Internet, and can also be found on the Cologne website at www.dopinginfo.de.

Events took a more sinister turn in 2002, when the laboratories in Cologne and in Vienna found one of the 'hard' anabolic steroids (methanedieneone) in a supplement purchased in England. This drug was present in high enough amounts not just to have an anabolic effect but also to produce serious side effects. The presence of this steroid has been described as a 'deliberate and criminal act (remember that this was the drug that caused problems for British athletes Janine Whitlock and Perris Wilkins).

So where are we now?

In some ways it does not help to know what was positive last year because the market keeps changing, with old products disappearing and new ones appearing on a regular basis. It is also true that products from the same batch, or even the same bottle, may be either clean or contaminated.

Ron Maughan

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1. *Dtsch Z Sporttned* 51, 11 (2000): pp378-382
2. *Dtsch Apoth Ztg* 142, 29 (2002): p50

Module 10

Evaluation Tests

Introduction

The success of the training program is largely dependent upon satisfying the performance aims associated with it.

How can performance be monitored?

Testing and measurement are the means of collecting information upon which subsequent performance evaluations and decisions are made.

Criticism

A major criticism of fitness testing is that it does not accommodate sport specific movements. One may suggest that to measure athletes on a treadmill running test is sport specific, but can this be related to hockey, football or rugby players who spend a considerable amount of time running sideways and backwards?

The challenge

Most fitness tests are used to assess basic fitness levels under the categories of strength, speed, stamina and suppleness. They serve only as an indication of an aspect of fitness. The challenge for the tester is to design tests that can be standardised and relate directly to a skill or a series of skills performed under pressure.

Overview of the articles in this section

In this section Brian Mackenzie explains:

- the objectives of testing, testing criteria and the limitations of testing
- how you can determine your VO_2 max in 12 minutes with the Cooper Test
- how to monitor the core muscle strength of your athletes
- how to monitor the aerobic capacity of your swimmers with the critical swim speed (CSS) test
- how to test your reaction speed with the drop ruler test
- how to monitor your explosive power with the Quadrathlon test
- how you can test you agility with the Illinois agility run test
- how you can monitor the elastic strength of your leg muscles with the vertical jump test

The articles in this section are applicable to most sports.

Why test?

What is the evaluation process?

The whole measurement/evaluation process is a six stage, cyclic affair, involving:

- The selection of characteristics to be measured.
- The selection of a suitable method of measuring
- The collection of that data
- The analysis of the collected data
- The making of decisions
- The implementation of those decisions

All of the above stages should be completed with the athlete – especially the analysis and making decision of appropriate corrective action

What are the requirements of a test?

In constructing tests it is important to make sure that they really measure the factors required to be tested, and are thus objective rather than subjective. In doing so all tests should therefore be specific (designed to assess an athlete's fitness for the activity in question), valid (test what they purpose to test), reliable (capable of consistent repetition) and objective (produce a consistent result irrespective of the tester).

In conducting tests the following points should be considered:

- Each test should measure ONE factor only.
- The test should not require any technical competence on the part of the athlete (unless it is being used to assess technique).

- Care should be taken to make sure that the athlete understands exactly what is required of him/her, what is being measured and why.
- The test procedure should be strictly standardised in terms of administration, organisation and environmental conditions.

What are the benefits of testing?

The results from tests can be used to:

- predict future performance
- indicate weaknesses
- measure improvement
- enable the coach to assess the success of his training programme
- place the athlete in appropriate training group
- motivate the athlete

Tests additionally break up, and add variety to, the training programme. They can be used to satisfy the athlete's competitive urge out of season. Since they demand maximum effort of the athlete, they are useful at times as a training unit in their own right.

What factors may influence test results?

The following factors may have an impact on the results of a test (test reliability):

- The ambient temperature, noise level and humidity
- The amount of sleep the athlete had prior to testing
- The athlete's emotional state
- Medication the athlete may be taking
- The time of day
- The athlete's caffeine intake
- The time since the athlete's last meal
- The test environment – surface (track, grass, road, gym)
- The athlete's prior test knowledge/experience
- Accuracy of measurements (times, distances, etc)
- Is the athlete actually applying maximum effort in maximal tests
- Inappropriate warm up
- People present
- The personality, knowledge and skill of the tester

Why record information?

For the coach it is important to monitor the programme of work, so as to maintain progression in terms of the volume of work and its intensity. Both coach and athlete must keep their own training records. A training diary can give an enormous amount of information about what has happened in the past and how training has gone in the past. When planning future training cycles, information of this kind is absolutely invaluable.

What should be recorded?

The information to be recorded falls into two broad categories: –

- The day-to-day information from training, *eg*
  - State of the athlete (health, composure)
  - Physiological data (body weight, resting heart rate, etc.)
  - The training unit (speed, speed endurance, strength, technique)
  - The training load (the number of miles, the number of sets and repetitions, the number of attempts)
  - The training intensity (kilograms, percentage of maximum, percentage of VO_2)
  - The prevailing conditions (wet, windy, hot, etc.)
  - The response to training (the assignments completed, the resultant heart rate recovery, felt tired, etc.)

- Information that measures status. This can take the form of a test. If the test is repeated throughout the programme, it can then be used as a measure of progress within the training discipline. Examples of such tests are:
  - Time trials – speed, speed endurance, endurance.
  - Muscular endurance – chins, push ups, dips.
  - Strength maximum – single repetitions, maximum repetitions.
  - Explosive strength – power bounding, vertical jump, overhead shot putt.
  - Mobility – objective measurements of the range of movement.
  - Event specific

Maximal tests

Maximal means the athlete works at maximum effort or tested to exhaustion. Examples of maximal anaerobic tests are:

- 30m sprint
- Wingate 30 second cycle ergometer test
- Example of maximal aerobic tests are:
- Multistage Fitness Test
- Cooper Test

Disadvantages of maximal tests are:

- difficulty in ensuring the subject is exerting maximum effort
- possible dangers of over exertion and injury
- dependent on the athlete's level of arousal

Submaximal tests

Submaximal means the athlete works below maximum effort. In submaximal tests extrapolation is used to estimate maximum capacity. Examples of submaximal aerobic test are:

- PWC 170 test
- Queen College step test

Disadvantages of submaximal tests are:
- depend on extrapolation being made to unknown maximum
- small measurement inaccuracies can result in large discrepancies as a result of the extrapolation

Brian Mackenzie

Cooper Test

Fitness can be measured by the volume of oxygen you can consume while exercising at your maximum capacity. VO_2 max is the maximum amount of oxygen in millilitres, one can use in one minute per kilogram of body weight. Those who are fit have higher VO_2 max values and can exercise more intensely than those who are not as well conditioned. The Cooper Test can be used to predict an athlete's VO_2 max.

Required resources

To undertake this test you will require:
- 400 metre track – marked every 50m
- stop watch
- an assistant

How to conduct the test

The test comprises of seeing how far an athlete can run/walk in twelve minutes. The assistant should record the total distance covered.

Performance assessment

Based on the distance covered an estimate of the athlete's VO_2 max can be calculated as follows:

VO_2 max = (Distance covered in metres – 504.9) / 44.73

Example

The athlete, a male football player, completes a total distance of 3400 metres in the 12 minutes.

VO_2 max = (3400 – 504.9) / 44.73
= 64.72 ml/kg/min

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 result from the Cooper Test can be used to:

- predict future performance
- indicate weaknesses
- measure improvement
- enable the coach to assess the success of his training programme
- place the athlete in appropriate training group
- motivate the athlete

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

The following factors may have an impact on the test result:

- The ambient temperature, noise level and humidity
- The amount of sleep the athlete had prior to testing
- The athlete's emotional state
- Medication the athlete may be taking
- The time of day
- The athlete's caffeine intake
- The time since the athlete's last meal
- The test environment – surface (track, grass, road, gym)
- The athlete's prior test knowledge/experience
- Accuracy of measurements (times, distances, etc)
- Is the athlete actually applying maximum effort in maximal tests
- Inappropriate warm up
- People present
- The personality, knowledge and skill of the tester
- Athlete’s level of motivation to give 100% effort

Validity

There are published VO_2 max tables and the correlation to actual VO_2 max is high.

Ideal VO_2 max scores for various sports

VO_2 max	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

Core Muscle Strength Test

The aim of core stability training is to ensure the deep trunk muscles are working correctly to control the lumbar spine during dynamic movements, *eg* lifting a heavy box or running. If core strength is poor then the torso will move unnecessarily during motion and waste energy. Good core strength indicates that the athlete can move with high efficiency.

The Core Muscle Strength Test can be used to monitor the development of the athlete's core strength.

Required resources

To undertake this test you will require:

- a flat surface
- an assistant
- a mat or something to support the elbows and arms and a watch.

How to conduct the test

The assistant is responsible for instructing the athlete as to the position to assume at the appropriate time sequence. Throughout the test the back, neck and head should be maintained in the posture as per Figure 1. If the athlete is unable to hold this position then the test is to be stopped.

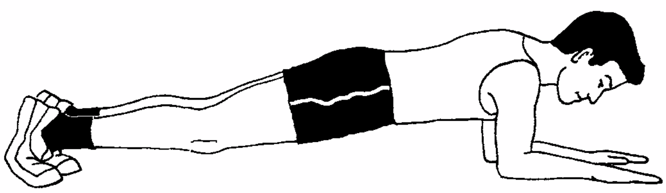


Figure 1

The Core Muscle Strength Test is conducted as follows:

Stage 1

- Using the mat to support your elbows and arms assume the Chinese Press Up position as in Figure 1 above
- Once the correct position is assumed the assistant starts the watch
- Hold this position for 60 seconds

Stage 2

- Lift your right arm off the ground
- Hold this position for 15 seconds

Stage 3

- Return your right arm to the ground and lift the left arm off the ground
- Hold this position for 15 seconds

Stage 4

- Return your left arm to the ground and lift the right leg off the ground
- Hold this position for 15 seconds

Stage 5

- Return your right leg to the ground and lift the left leg off the ground
- Hold this position for 15 seconds

Stage 6

- Lift your left leg and right arm off the ground
- Hold this position for 15 seconds

Stage 7

- Return you left leg and right arm to the ground
- Lift your right leg and left arm off the ground
- Hold this position for 15 seconds

Stage 8

- Return to the basic Chinese Press Up position – as in Figure 1 above
- Hold this position for 30 seconds

Stage 9

- End of test

Record the stage at which the athlete is unable to maintain the correct body position or is unable to continue with the test.

Analysis

Analysis of the result is by comparing it with previous test results. It is expected that, with appropriate training between each test, the analysis would indicate an improvement. If the athlete is able to complete the test, up to and including stage 8, then it indicates they have good core strength.

Brian Mackenzie

Critical Swim Speed

Objective

The Critical Swim Speed (CSS) test, devised by Ginn [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
- An 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 of 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.

Brian Mackenzie

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: pp153-157

Drop Ruler Test

Reaction time is the interval of time between the presentation of a stimulus and the initiation of the muscular response to that stimulus *eg* the sprinter's reaction to the starter's gun or the reaction of the tennis player receiving a 100mph serve.

Equipment

To undertake this test you will require a 30 cm/12 inch ruler and an assistant.

Warm up

Allow the athlete to have three practices before conducting the test formally.

How to conduct the test

The ruler is held by the assistant between the outstretched index finger and thumb of the athlete's dominant hand, so that the top of the athlete's thumb is level with the zero cm line on the ruler. The assistant instructs the athlete to catch the ruler as soon as possible after it has been released.

The assistant records distance between the bottom of the ruler and the top of the athlete's thumb where the ruler has been caught.

Analysis

The algorithm to calculate the reaction speed is $d = vt + \frac{1}{2}at^2$ where

- d = distance in cm
- v = initial velocity = 0
- a = acceleration due to gravity = $9.81 m/s^2$
- t = time in m/s

We need to manipulate $d = vt + \frac{1}{2}at^2$ to give us an algorithm for t.

As $v = 0$ then $vt = 0$ therefore the algorithm is $t = \sqrt{(2d/a)}$

Example

The athlete catches the ruler at the 9cm mark on the ruler.

- $d = 9$ cm
- $t = \sqrt{(2 * 9/9.81)}$
- $t = 1.35$ m/s

Calculators

The following table can be used to determine an athlete's reaction time:

Distance cm	Time msec
1	0.45
2	0.64
3	0.78
4	0.90
5	1.01
6	1.11
7	1.19
8	1.28
9	1.35
10	1.43

Distance cm	Time msec
11	1.50
12	1.56
13	1.63
14	1.69
15	1.75
16	1.81
17	1.86
18	1.92
19	1.97
20	2.02

If you wish to save time and avoid the mathematics then use the following table to calibrate your ruler in milliseconds

Time msec	Distance cm
0.2	0.20
0.4	0.78
0.6	1.77
0.8	3.14
1.0	4.91
1.2	7.06

Time msec	Distance cm
1.4	9.61
1.6	12.56
1.8	15.89
2.0	19.62
2.2	23.74
2.4	28.25

Brian Mackenzie

The Quadrathlon

The Quadrathlon was devised in 1982 to test for explosive power improvement of the Great Britain National Throws Squad. The test is easy to carry out and is an excellent way to analyse an athlete's fitness and progress during the winter months.

The Quadrathlon comprises of four activities:

- Standing long jump
- Three jumps
- 30 metre sprint
- Overhead shot throw

Practical Uses

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

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

How to conduct the test

Each of the four activities is undertaken three times and the best score recorded. Scores are then converted to points using the Quadrathlon tables (see the section Quadrathlon Tables below) and the points totalled to give a final score. An explanation of each activity is detailed below:

Standing Long Jump

- Place the feet over the edge of the sandpit, crouch down, swing the arms backwards, swing the arms forward and jump 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.

Three Jumps

- Start with the feet comfortably apart with the toes just behind the take off mark. The athlete takes three continuous two footed bounds. Measure the distance covered. The start must be from a static position and the feet must be parallel on each jump phase. Spikes allowed.

30 Metre Sprint

- On the start signal the athlete sprints from a stationary position (standing or block start) as fast as possible to the 30m finish line. The time keeper stands at the finish line and times the run from the moment that the runner contacts the ground on the first stride to the moment when the runner's torso crosses the line. Spikes allowed.

Overhead Shot Throw

- The athlete stands on the shot stop board, facing away from the landing area, with their feet a comfortable distance apart. The shot is held cupped in both hands. The athlete crouches, lowering the shot between the legs, then drives upwards to cast the shot back over the head. There is no penalty for following through, but the athlete must land feet first and remain upright. Measurement is taken from the inside of the stop board to the nearest point of contact. Shot weight as per competition. Please watch the safety aspect.

Analysis

Analysis of the scores 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. 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.

Quadrathlon tables

Points are allocated from the Quadrathlon tables depending on the distance or time achieved for each activity. 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 full tables are not provided here but the number of points for each event can be calculated using the following equations:

Activity	Points Equation
Standing Long Jump	Points = -36.14048 + (D x 37.268536) + (D x D x -0.128057)
Three Jumps	Points = -36.36996 + (D x 12.478922) + (D x D x -0.007423)
30 Metre Sprint	Points = 209.70039 + (T x -36.94427) + (T x T x 0.165766)
Overhead Shot	Points = -22.32216 + (D x 5.8318756) + (D x D x -0.000334)
Where D is the distance in metres and T is the time in seconds	

A copy of the Quadrathlon tables can be obtained by emailing brian@brianmac.demon.co.uk

British all time lists

Name	Event	3 Jumps	SLJ	30m	OH Shot	Points
M Winch	Shot	10.31	3.12	3.56	18.57	338
D Thompson	Decathlon	9.51	3.07	3.40	17.36	321
J Regis	200m	10.24	3.14	3.41	15.34	321
C Court	Heptathlon	8.38	2.79	3.68	16.54	283
T Sanderson	Javelin	7.97	2.66	3.89	15.48	259
J Oakes	Shot	7.22	2.55	4.01	17.88	256

The following test results indicate an athlete may mature into a high standard club athlete.

Boys				
Event/Age	14	15	16	17
30 metres	4.15	4.00	3.90	3.75
SL Jump	2.35	2.60	2.75	2.90
3 Jumps	7.20	7.60	8.25	8.70
OH Shot	15.00	15.50	17.20	18.00
	4kg	5kg	5kg	7.26kg

Girls				
Event/Age	14	15	16	17
30 metres	4.35	4.20	4.10	4.00
SL Jump	2.15	2.30	2.40	2.60
3 Jumps	6.40	7.05	7.20	7.70
OH Shot	13.20	13.40	14.10	15.00
	3.25kg	4kg	4kg	4kg

Target group

This test is suitable for all athletes, primarily power athletes, 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

The Illinois Agility Run Test

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.

Objective

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

Required resources

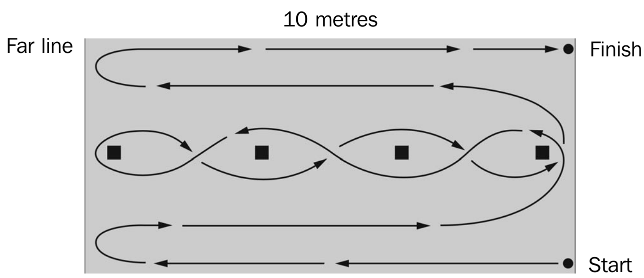
To undertake this test you will require:

- flat surface – a 400m Track
- eight cones
- stop watch
- an assistant

The Illinois course

The length of the course is 10 metres and the width (distance between the start and finish points) is five metres. On the track you could use five 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 his/her 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.

Performance assessment

Time in Seconds		Rating
Males	Females	
<15.2	<17.0	Excellent
16.1-15.2	17.9-17.0	Good
18.1-16.2	21.7-18.0	Average
20.3-18.2	23.0-21.8	Fair
>20.3	>23.0	Poor

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

Vertical Jump Test

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.

Objective

The objective of this test is to monitor the development of the athlete's elastic leg strength.

Required resources

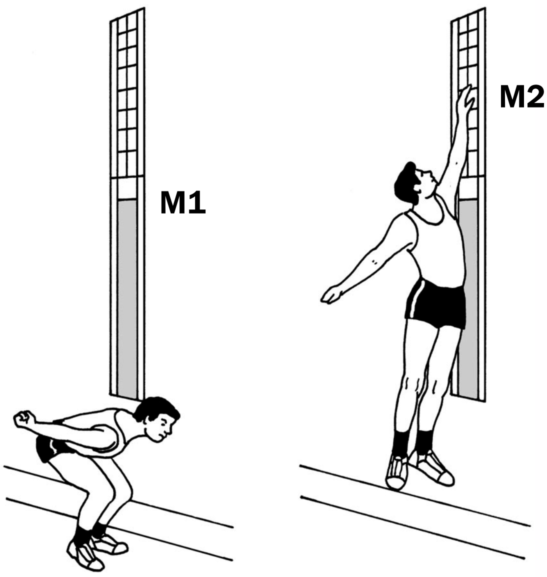
To undertake this test you will require:

- a wall
- a one-metre tape measure
- chalk
- an assistant

How to conduct the test

The athlete:

- chalks the end of his finger tips
- stands side onto the wall, keeping both feet remaining on the ground, reaches up as high as possible with one hand and marks the wall with the tips of the fingers (M1)
- from a static position jumps as high as possible and marks the wall with the chalk on his finger tips (M2)



The coach then measures the distance from M1 to M2. The test can be performed as many times as the athlete wishes.

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.

Performance assessment

Distance in CM		Rating
Males	Females	
>56	>36	Excellent
51-56	31-36	Good
45-50	25-30	Average
39-44	19-24	Fair
<39	<19	Poor

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 11

Competition Preparation

Introduction

All athletes are nervous prior to competition, this is natural, but often it results in a lack of confidence by the athlete. The aim is to refocus the athlete so that they are positive and confident in their ability ("You only achieve what you believe"). What athletes do in the hours leading up to competition may well impact their performance.

Overview of the articles in this section

- Brian Mackenzie reviews the benefits and process of carbohydrate loading
- Janet Stansfeld provides a sport by sport survey of the best food to eat before a competition
- Brad Walker explains the four key stages of an effective and complete warm up
- Brian Mackenzie provides guidelines about eating and competing, which will help you to perform at your best during competition

The articles in this section are applicable to most sports.

Carbohydrate loading

The discovery that it is possible to boost energy reserves by eating large amounts of carbohydrates after a period of intensive exercise represented a major breakthrough in the field of exercise physiology. This new knowledge led to the development of the popular carbohydrate-loading regime aimed at increasing energy stores, thereby enhancing endurance performance. Endurance athletes rely on their glycogen reserves as a source of energy during competition.

Over the years, a variety of carbo-loading regimes have been developed and used by endurance athletes. Probably the most widely used regime involves athletes reducing their training load for up to six days before competition while simultaneously consuming a carbohydrate-rich diet. But is it really necessary for athletes to disrupt their training schedules for such extended periods?

Carbohydrate loading is a legal method of boosting the amount of glycogen in the body prior to a competition

What is the process?

Six days prior to a competition the process begins. For the first three days the athlete consumes minimal carbohydrate and exercises so as to deplete the body's glycogen stores. In the last three days the athlete consumes primarily carbohydrate and reduces the training load.

So what is the theory?

At the end of day three the body will think that there is a problem with its glycogen stores and that it should store more glycogen than normal.

In the last three days, when the athlete consumes carbohydrate, the body will replenish the glycogen stores and hopefully top them up with a little bit extra.

Caution

In the first three days ensure adequate carbohydrates (about 60grm per day) are consumed to maintain the functioning of several important systems in the body.

In the last three days the diet should be primarily carbohydrate, do not over eat, but you do need to consume adequate protein, minerals, vitamins and fluid. You will find that you will need to consume larger amounts of fluid than normal. Monitor your urine, it should be clear, to ensure you are drinking sufficient.

If you decide to try carbohydrate loading then try it in stages during your training. Start with depletion, low carbohydrate diet for one day, high carbohydrate diet. If no adverse effects then extend the period of the low carbohydrate diet to a maximum of three days. Keep a detailed log of what you do and what happens.

The bad news

Some of the potential side effects of carbohydrate loading are:

- Muscle stiffness
- Diarrhoea
- Chest Pain
- Depression
- Lethargy

The benefits of rapid carbo-loading

A study [1] examined the impact on performance of using a much less disruptive one-day loading regime. Subjects were required to consume 10.2g of carbohydrate per kg of body weight per day (*ie* more than 700g of carbohydrates per day for an athlete weighing 70kg) while remaining inactive for just 24hrs.

Using muscle biopsies, the researchers were able to establish that muscle glycogen levels rose by 90% over 24 hours, showing that that it is possible to boost energy stores significantly within a relatively brief timescale.

This welcome discovery adds to the range of choices athletes can make when it comes to nutritional strategies aimed at enhancing performance.

The advantage of the standard loading regime is that it allows for a longer taper prior to a major competition, giving your body time to recover from previous exertions as well as build up its energy stores.

Brian Mackenzie

Reference

1. *European Journal of Applied Physiology*, vol 87: pp290-295, 2002

What to eat before competing

Can you give your performance an edge by fuelling up before exercise? Well, sometimes yes, sometimes no, and sometimes it can even have a negative effect. Here are the guidelines.

The main nutrient to watch in this context is, of course, carbohydrate as glycogen (the body's carbohydrate store) is the limiting fuel for endurance exercise. Eating a diet high in carbohydrates while training should ensure that you have good muscle glycogen stores prior to competing. Available evidence shows that topping up with extra carbohydrate just before the action has a negligible effect on events of short or moderate duration (less than 60 minutes). It is like adding an extra gallon of petrol to a car with a full tank before a short journey. But if your initial glycogen levels are low (*eg* if you are participating in a tournament taking place over a week) and/or the exercise lasts 90 minutes or longer, pre-exercise carbohydrate may improve your performance.

The type of food and its timing is crucial to whether it is helpful or harmful. Some basic physiology should help explain why this is. Exercising muscles burn fat and glucose. The glucose is obtained both from the glycogen stores in the muscles, and from glucose circulating in the blood. The liver has the task of masterminding blood glucose levels and trying to ensure that they do not dip too low (causing hypoglycaemia, resulting in weakness, dizziness and nausea). If the liver registers that blood glucose levels are dropping, it can release glucose into the blood from its own glycogen store. If blood glucose levels rise (*eg* after eating food containing carbohydrate) the hormone insulin is released, which forces glucose out of the bloodstream and into storage as glycogen.

The relevance of this to pre-exercise nutrition is as follows. During a fasting period (such as overnight), liver glycogen stores will be lowered. If you compete in a morning event without having eaten anything since the night before, you are starting at a disadvantage. Although your muscle glycogen will still start off high, once it begins to be used up (after an hour or so) there is a reduced amount of blood glucose supplied by the liver to turn to. You can avoid this problem by eating a high-carbohydrate meal one to four hours before exercise. The available evidence suggests that the optimal amount is somewhere between one to 4g of carbohydrate per kg of body weight. The amount of carbohydrate should be less the nearer to competing to avoid gut problems. ('Carbohydrates' in Berning, J. and Nelson-Steen, S., *Sports Nutrition for the 90s*, Aspen, Maryland, 1991).

Avoiding the hypoglycaemic backlash

The insulin response is more difficult to pin down. Some carbohydrates cause a more marked surge in blood glucose (and hence insulin) than others. Measurements have been made and foods categorised according to their 'Glycaemic index' (see table). A food's glycaemic index (GI) gives an indication of the degree of blood-glucose surge to expect. High-GI foods (which include glucose itself and bread, bananas) bring about a marked and immediate rush of glucose into the bloodstream, whereas low-GI foods (*eg* beans, lentils) release glucose at a slow and steady rate over a much longer time period. There is a potential problem with high-GI foods. The high insulin response can actually lead to an over enthusiastic hoarding away of blood glucose, leading in turn to a net blood-sugar drop and its unwelcome effects. Some individuals seem to be more susceptible to this problem than others, however, which may help to explain why research studies have come up with apparently contradictory information in this area.

For some time in sports nutrition it has been accepted wisdom that sugar should not be consumed within the 60 to 15 minutes prior to exercise for fear of a hypoglycaemic backlash. Several early studies found that run-time to exhaustion was shorter by about 20 to 25% after athletes consumed two to 3oz of glucose within an hour before an endurance test. However, a number of more recent studies have not found this effect. Research carried out at the Gatorade Sports Science Institute in Illinois found that pre-exercise feedings of carbohydrate (6% sucrose/glucose solution or a 20% maltodextrin/glucose solution) did not result in hypoglycaemia, or adversely affect sensory or physiological responses during 50 minutes of moderate-intensity cycling. Exercise was started at the time of the individual's peak insulin response (usually somewhere between 20 to 45 minutes after carbohydrate consumption). Although blood sugar did drop when exercise commenced, it did not reach significantly low levels and returned to baseline values after 30 minutes of exercise. The volunteer cyclists were not aware of any subjective problems, such as perceived muscle weakness or nausea, during the exercise ('Glycaemic and Insulinemic Response to Pre-exercise Carbohydrate Feedings', Seifert, J., et al, *International Journal of Sport Nutrition*, 4: pp46-53, 1994).

Other research has found that the best food to take an hour before activity is carbohydrate that has a low glycaemic index. Scientists at the University of Sydney tested out four different pre-race feeds: (1) boiled lentils (2) baked potatoes (3) a sports drink comprising glucose dissolved in water, and (4) plain water. Volunteers cycling to exhaustion averaged 117 minutes with the lentils compared with 108 minutes for the sports drink and only 97 minutes with potatoes. There seemed to be a link to blood glucose levels after 90 minutes. Blood glucose was about 20% higher for the lentil eaters compared to those who took the sports drink ('Carbohydrate Feeding before Exercise: Effects of Glycaemic Index', *International Journal of Sports Medicine,* vol 12 (2): pp180-186, 1991). So there may be a benefit from a pre-exercise meal of lentils or the like if:

- you are going to be active for over an hour
- you think you suffer from reactive hypoglycaemia
- you are unable to take in any extra carbohydrates as you go

Cannot stand lentils? Check the table for other low-GI foods

Another strategy, which should suit everybody, whether or not you have a tendency to hypoglycaemia, is to take in carbohydrate 5 to 10 minutes before exercise of an hour or more. If you are exercising at an intensity greater than 50% VO_2 max, the insulin response to glucose ingestion is suppressed. Choose something that will be absorbed quickly, either a sports drink or a high-GI food (solid food is not recommended for runners so close to racing – take the risk only if you know your gut can handle it!).

Here are my recommendations for specific sports:

Running

Sprinting

You will not benefit from extra carbohydrates before competing, as glycogen stores are not a limiting factor. However, it might be worth taking some sodium bicarbonate before racing but the research is split down the middle. About half the studies have found a benefit, the other half no effect. No serious detrimental effects have been found, however, apart from nausea in susceptible individuals. A dose of 300mg per kg of body weight has been found effective in some studies for exercise lasting between 30 to 120 seconds (*eg* 800m track). It is probably best to take this one to three hours before racing ('Bicarbonate Loading', Heigenhauser, G. and Jones, N. In Lamb, D. and Williams (eds), *Ergogenics, Enhancement of Performance in Exercise and Sport*, Brown & Benchmark, Iowa, 1991).

Middle distance

Depending on your level of fitness and the terrain involved (*eg* hills vs. flat running), glycogen may or may not be a limiting factor. Make sure you have had a high-carbohydrate meal two to three hours beforehand if possible. Taking extra carbohydrates on board in the 10 minutes before racing probably will not hinder your performance but it is doubtful it will have any positive effect either! Caffeine before running may improve your capacity to 'kick' at the end of a race. A study found that two cups of strong coffee brought about a significant improvement over 1500m. For peak absorption, drink about an hour before exercise ('Effect of Caffeinated Coffee on Running Speed, Respiratory Factors, Blood Lactate and Perceived Exertion During 1500m Treadmill Running', *British Journal of Sports Medicine*, 26(2): pp116-120, 1992).

Endurance

If you are running for over an hour, extra carbohydrates before and during a run may well help your performance. The amount of carbohydrate ingested four hours prior to performance should be based on body weight. Several studies have used four to 5g/kg with good results. For an athlete who weighs 60kg (132 pounds), the recommended amount would be 240 to 300g. The carbohydrates could be consumed in any of several forms, including fluids such as juices or glucose polymer solutions, or solid carbohydrates such as fruits or starches. The fibre content should be minimised to prevent possible intestinal problems during exercise. If carbohydrate is consumed approximately one hour before competing, one to 2g/kg has been found to enhance performance in several studies. Both glucose polymers and foods with a low glycaemic index have been used successfully. If carbohydrate is consumed immediately before exercise, *ie* within 10 minutes of the start, about 50 to 60g of a glucose polymer in a 40 to 50% solution has been used effectively in some studies.

A blight of many distance runners is gut and bowel problems. If you suffer from this, choose your foods carefully. It is probably wise to avoid food high in fibre, and you should certainly avoid fatty foods. Try liquid meals but choose between those formulated for athletes, for convalescents (check for a high carbohydrate content) or make your own by blending milk, skimmed milk powder and fruit.

Cycling

The advice is similar to that for equivalent distances in running. However, cyclists are less prone to gut problems, so will be able to tolerate solid food before competing. Caffeine has been shown to enhance cycle sprint ability as well as endurance capacity (the evidence is more convincing than for distance running). Individuals vary in their response and toleration for caffeine, so test it out in training.

Racket sports (squash, tennis, badminton, etc)

Compared to athletic events such as running and cycling, nutrition research related to racket sports is sparse. However, general guidelines can be put together by looking at the type of exercise involved. Most court games require a combination of strength, endurance and sprinting capacity, taxing both aerobic and anaerobic metabolism. As with any activity, the longer it goes on, the more likely that glycogen will become limiting. This means that it makes sense to eat a high-carbohydrate diet, and that taking in extra carbohydrate before playing may bring some benefit. As already mentioned, the timing of this may be crucial if you are a hypoglycaemic reactor.

A study on 28 elite tennis players found that blood sugar levels were far better behaved if a muesli bar was eaten 15 minutes before a game, compared to eating the bar 45 minutes before. The research, carried out at the University of Cologne, found that eating the bar 45 minutes before activity led to a swoop in blood-glucose levels to 25% below normal ('Blood Sugar Levels and Carbohydrate Substitution in Tennis', I*nternational Journal of Sports Medicine*, vol 14: p163, 1993). Given the nature of the activity, it would probably be even better to have a carbohydrate containing sports drink rather than solid food, less chance of gut gremlins!

Glycaemic index (GI) of selected foods

High GI	Medium GI	Low GI
Bread (white and wholemeal), rye bread, bagels, rice (white and brown), cornflakes, muesli, Weetabix, semi-sweet biscuits, plain crackers, rye crispbread, potatoes, sweetcorn, parsnips, raisins, bananas, 6% sucrose, 20% maltodextrose	Spaghetti, macaroni, noodles (Oriental), porridge, oatmeal biscuits, plain sweet biscuits, sponge cake, sweet potato, potato crisps, grapes, oranges	Baked beans, chick peas, red lentils ice cream, milk, yoghurt, tomato soup, apples, apple sauce, cherries, dates(dried), peaches, plums, tinned grapefruit, fructose

Field team sports (e.g. football, hockey)

These sports involve a lot of running although the participants may not identify as 'runners'. Investigations have found that soccer players cover at least 9000 to 11000 metres during a typical match, mixing jogging, sprinting and walking. It is a type of exercise guaranteed to use up muscle glycogen rapidly. This will start to bite in the second half of a match. Players who have used up their glycogen credit will find it more and more of a struggle to muster anything faster than a walk. Players will put themselves at an advantage by eating a diet that is generally high in carbohydrates. Before a match, a high carbohydrate snack five to 10 minutes prior to play may bring some benefit, as will drinking a sports drink (probably an isotonic containing glucose polymers) at half-time.

Rowing

At competition level, pre-race nutrition may be dictated mainly by trying to compensate for drastic dehydration regimes undertaken to make weight. A typical regime is severe fluid restriction combined with reduced food intake and heavy exercise in the days before an event. Do not do it! It is not possible in the time remaining to normalise your physiology and restore full blood volume. A study simulating these conditions found that only half of the lost blood plasma was restored during fluid intake after weighing. This put a significant downer on performance over a 2000m course, those who had dehydrated and attempted to rehydrate were 15 metres behind. It is far better to go for a long-term weight control plan, and to start the race fully hydrated ('Rowing Performance, Fluid Balance and Metabolic Function following Dehydration and Rehydration', *Medicine and Science in Sports and Exercise*, 25(12): pp1358-1364).

Final considerations

There is a lot of individual variation in response to different foods. The only person who can really know what is going to work best is you. Use the research findings as a guide, and then try out different strategies in training.

Although taking in some extra carbohydrate before competing can enhance endurance performance, the optimum regime is to do this AND to take in extra carbohydrates while active (probably best in the form of a drink).

No last minute food will make up for a poor diet in previous weeks. Give yourself a serious head start by eating a high carbohydrate diet during training.

Janet Stansfeld

Warm up properly, and reduce the risk of sports injury

The warm up activities are a crucial part of any exercise regime or sports training. The importance of a structured warm up routine should not be under estimated when it comes to the prevention of sports injury.

The warm up

An effective warm up has a number of very important key elements. These elements, or parts, should all be working together to minimise the likelihood of sports injury from physical activity.

Warming up prior to any physical activity does a number of beneficial things, but primarily its main purpose is to prepare the body and mind for more strenuous activity. One of the ways it achieves this is by helping to increase the body's core temperature, while also increasing the body's muscle temperature. By increasing muscle temperature you're helping to make the muscles loose, supple and pliable.

An effective warm up also has the effect of increasing both your heart rate and your respiratory rate. This increases blood flow, which in turn increases the delivery of oxygen and nutrients to the working muscles. All this helps to prepare the muscles, tendons and joints for more strenuous activity.

Keeping in mind the aims or goals of an effective warm up, we can then go on to look at how the warm up should be structured.

Obviously, it's important to start with the easiest and most gentle activity first, building upon each part with more energetic activities, until the body is at a physical and mental peak. This is the state in which the body is most prepared for the physical activity to come, and where the likelihood of sports injury has been minimised as much as possible. So, how should you structure your warm up to achieve these goals?

There are four key elements, or parts, which should be included to ensure an effective and complete warm up. They are:

1. The general warm up
2. Static stretching
3. The sports specific warm up
4. Dynamic stretching

All four parts are equally important and any one part should not be neglected or thought of as not necessary. All four elements work together to bring the body and mind to a physical peak, ensuring the athlete is prepared for the activity to come. This process will help ensure the athlete has a minimal risk of sports injury. Let's have a look at each element individually.

1. The general warm up

The general warm up should consist of a light physical activity. Both the intensity and duration of the general warm up (or how hard and how long), should be governed by the fitness level of the participating athlete. Although a correct general warm up for the average person should take about five to ten minutes and result in a light sweat.

The aim of the general warm up is simply to elevate the heart rate and respiratory rate. This in turn increases the blood flow and helps with the transportation of oxygen and nutrients to the working muscles. This also helps to increase the muscle temperature, allowing for a more effective static stretch.

2. Static stretching

Static stretching is a very safe and effective form of basic stretching. There is a limited threat of injury and it is extremely beneficial for overall flexibility. During this part of the warm up, static stretching should include all the major muscle groups, and this entire part should last for about five to ten minutes.

Static stretching is performed by placing the body into a position whereby the muscle or group of muscles to be stretched is under tension. Both the opposing muscle group (the muscles behind or in front of the stretched muscle), and the muscles to be stretched are relaxed. Then slowly and cautiously the body is moved to increase the tension of the muscle, or group of muscles to be stretched. At this point the position is held or maintained to allow the muscles and tendons to lengthen.

This second part of an effective warm up is extremely important, as it helps to lengthen both the muscles and tendons which in turn allow your limbs a greater range of movement. This is very important in the prevention of muscle and tendon injuries.

The above two elements form the basis, or foundation for a complete and effective warm up. It is extremely important that these two elements be completed properly before moving onto the next two elements. The proper completion of elements one and two, will now allow for the more specific and vigorous activities necessary for elements three and four.

3. Sport specific warm up

With the first two parts of the warm up carried out thoroughly and correctly, it is now safe to move onto the third part of an effective warm up. In this part, the athlete is specifically preparing their body for the demands of their particular sport. During this part of the warm up, more vigorous activity should be employed. Activities should reflect the type of movements and actions which will be required during the sporting event.

4. Dynamic stretching

Finally, a correct warm up should finish with a series of dynamic stretches. However, this form of stretching carries with it a high risk of injury if used incorrectly. It should really only be used under the supervision of a professional sports coach or trainer. Dynamic stretching is more for muscular conditioning than flexibility and is really only suited for professional, well trained, highly conditioned athletes. Dynamic stretching should only be used after a high level of general flexibility has been established.

Dynamic stretching involves a controlled, soft bounce or swinging motion to force a particular body part past its usual range of movement. The force of the bounce or swing is gradually increased but should never become radical or uncontrolled.

During this last part of an effective warm up it is also important to keep the dynamic stretches specific to the athlete's particular sport. This is the final part of the warm up and should result in the athlete reaching a physical and mental peak. At this point the athlete is most prepared for the rigors of their sport or activity.

The above information forms the basis of a complete and effective warm up. However, I am well aware that this entire process is somewhat of an 'ideal' or 'perfect' warm up. I am also well aware that this is not always possible or convenient in the real world. Therefore, the individual athlete must become responsible for assessing their own goals and adjusting their warm up accordingly.

For instance, the time you commit to your warm up should be relative to your level of involvement in your particular sport. So, for people just looking to increase their general level of health and fitness, a minimum of five to ten minutes would be enough. However, if you are involved in high level competitive sport you need to dedicate adequate time and effort to a complete warm up.

Brad Walker

Competition and eating

What you eat on a day-to-day basis is extremely important for training. Your diet will affect how fast and how well you progress, and how soon you reach competitive standard. But once you are ready to compete, you will have a new concern: your competition diet. Is it important? What should you eat before your competition? When is the best time to eat? How much should you eat? Should you be eating during the event? And what can you eat between heats or matches? A lot of research has been done in this area, and it is clear that certain dietary approaches can enhance competition performance. This page gives guidelines about eating and competing, which will help you to perform at your best during competition.

What should you eat in the week before a competition?

During the week before a competition you should fill up your glycogen stores so that you begin your competition with a full fuel supply. This is especially important if you are competing in an endurance sport or competing in a number of heats over a short period. The way to increase your glycogen stores is to taper training during the final week before a competition, and to increase carbohydrate intake. Eat plenty of complex carbohydrate foods, especially those with a low glycaemic index to help boost your glycogen stores. For the last three to four days try to eat a small meal or snack every two or three hours. Plan each meal around high-carbohydrate foods, for example baked potatoes, bread or pasta. Your total energy intake should remain about the same as usual. Eat smaller portions of high-protein foods such as meat, fish and eggs. Keep fat intake to a minimum and eat larger amounts of carbohydrate rich foods (*ie* potatoes, pasta, cereals, etc). During these last few days you should, ideally, be getting 60 to 70% of your energy from carbohydrates.

What should you eat before competition?

Hopefully, by the morning of your competition, the previous day's eating will already have filled your glycogen stores. Your pre-competition meal should be high in carbohydrate, low in fat, low in protein, low in fibre (*ie* not too bulky and filling), enjoyable and familiar. Eat complex carbohydrates as these release energy slowly. Avoid simple carbohydrates as these release energy quickly but trigger the release of insulin which can soon make you feel tired. Suitable types of food include: breakfast cereals, porridge, bread, rolls, toast, fruit juice, fruit, rice cakes, plain crackers, boiled rice, potatoes, sweet potatoes, yams, boiled pasta, dried fruit, oatmeal biscuits, plain wholemeal biscuits, muffins and carbohydrate drinks.

Must you eat a pre-competition meal?

Many competitors feel nervous on the day of the competition and do not want to eat. However, it is not a good idea to avoid having a pre-competition meal. Your liver glycogen stores will be low and could adversely affect your performance in the last stages if you are competing in an endurance event (or in one that lasts over 1.5 hours). The liver can only store enough glycogen to last 12 hours, so if you eat nothing after the previous day's evening meal your liver glycogen stores will be considerably depleted. If you really do not feel like eating, try to have a liquid meal such as a carbohydrate drink, some fruit juice or commercial sports drink.

Should you eat just before the competition?

Studies have shown that eating a small amount (about 50gms) of fast absorbing carbohydrate just before exercise helps to delay fatigue and improve endurance. Carbohydrates with a high glycaemic index are absorbed relatively quickly into the bloodstream and cause a fairly rapid rise in blood-sugar levels. If you start exercising within about five minutes, an increase in insulin will be prevented and your blood sugar levels will remain slightly raised for longer. Some people are more sensitive to blood sugar fluctuations than others, so you may find that this last-minute snack does not suit you at all.

Should you eat or drink during a competition?

If you are competing for more than an hour, you may find that taking extra carbohydrate during the event helps to delay fatigue and maintain exercise intensity, particularly during the later stages. If you take small amounts of carbohydrate at regular intervals during the competition, blood sugar levels will be boosted and glycogen stores will not be depleted so rapidly. If you are competing in a tournament or match which involves intermittent, high and low-intensity activity, and which lasts for over an hour, try to have some form of carbohydrate during the breaks.

Make sure you are well hydrated before the competition by having your last drink about 15 to 20 minutes before the start. Drink at regular intervals (150 to 300ml), ideally every 15 minutes or whenever you have a break during competition. Do not wait until you feel thirsty, you will already be dehydrated. Water is fine or you may prefer to use a commercial carbohydrate drink (Sports Drinks) as this will also refuel your glycogen stores.

What should you eat after competition?

Following training & competition an athlete's glycogen stores are depleted. In order to replenish them the athlete needs to consider the speed at which carbohydrate is converted into blood glucose and transported to the muscles. The rapid replenishment of glycogen stores is important for the track athlete who has a number of races in a meeting. The rise in blood glucose levels is indicated by foods Glycaemic Index (GI) and the faster and higher the blood glucose rises the higher the GI.

Studies have shown that consuming high GI carbohydrates, approximately 2g/kg of body weight, and 40g of protein within 2 hours after exercise speeds up the replenishment of glycogen stores and therefore speeds up recovery time. It appears that the muscles are more receptive to and retaining carbohydrates during the two hours after exercise.

Brian Mackenzie

Contributors

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