# Modern Speed Training A Comprehensive Guide <br> <br> by Adrian Faccioni 

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## Chapter 1:

## THE PHYSIOLOGY OF SPEED

The question of what makes one person faster than another is frequently asked in those sports where speed is an important component of success. The answer is a complex one, as many variables are involved in an athlete's overall performance.

The major variables which influence speed performance are:

- muscle type (fibre make-up);
- neural processes;
- technique;
- anatomy (size);
- strength and power levels; and
- availability of energy supply.

This chapter will attempt to explain the complex matrix of the above variables which leads to superior speed performance.

## 1. MUSCLE TYPE

Muscles are made up of two major fibre types: slow-twitch (type 1 or red) fibres and fast-twitch (type 2 or white) fibres. The characteristics of these fibres differ greatly (see Figure la).

|  | Fast-Twitch Fibres | Slow-Twitch Fibres |
| :--- | :--- | :--- |
| Aerobic Capacities |  |  |
| Mitochondria | low | high |
| Aerobic metabolism | low | high |
| Fatigue resistance | low | high |
| Anaerobic Capacities |  |  |
| Glycogen stores | high | low |
| Anaerobic metabolism |  | high |
| Speed of contraction | high |  |

Force of contraction high low

Figure 1a. Differences between fast-twitch and slow-twitch muscle fibres

## Explanation of Terms

- Mitochondria - energy-producing cellular component used during aerobic exercise
- Aerobic metabolism - process where energy is produced using oxygen
- Fatigue resistance - muscle fibre's ability to resist fatigue from repeated contractions
- Glycogen stores - short-term energy storage facility of muscle fibres
- Anaerobic metabolism - ability of muscle fibre to produce energy without oxygen (requires glycogen)
- Speed of contraction - ability of muscle fibre to contract repeatedly and quickly
- Force of contraction - ability of muscle fibre to contract strongly

The speed athlete has a predominance of fast-twitch muscle fibres, those that allow for fast contraction speeds and great force production, two factors that contribute to increased movement speed in athletes.

Each person has two types of fast-twitch fibres: type 2A, or fatigue-resistant, and type 2 B , or easily fatigued. Too much endurance training without concomitant speed and power training leads to the type 2B fibres becoming more like the type 2 A fibres, and the type 2A fibres becoming more like the type 1 fibres. In other words, excessive and incorrect endurance training by speed and power athletes can decrease their potential fast-twitch muscle content, making their muscle attributes more like those of an endurance athlete. Endurance training should be modified to minimise such effects.

## (See Chapter 7 for more information on this topic)

Research has also documented that it seems to be easier to convert the characteristics of fast-twitch fibres to those of slow-twitch fibres than it is to convert slow-twitch to fast-twitch. It is therefore essential that the coach and athlete do not at any time during the training year totally sacrifice speed through long periods of endurance training (typically what all team-sport athletes do following the end of their competition phase). Endurance can be developed with minimal reduction in speed
through the correct periodisation of all training elements. (See Chapter 15 for more information on this topic)

## 2. NEURAL PROCESSES

The sprint athlete may have a greater neural output (related to muscle fibre types) than the endurance-trained athlete. Their nerve conduction velocities don't vary much from those of the general public (implying that other factors are more relevant to sprint speed) but are higher than those of endurance-trained athletes. This suggests that an increase in neural conduction velocity is largely dependent upon environmental influences (e.g. training). Weight-lifters who stress the neural system every single training session have the fastest ulnar (arm) and posterior tibial nerve (leg) conduction velocities of all athletes tested for this. It is believed that overloading a muscle through training can increase nerve axon diameters. Nerve axon diameters are correlated to conduction velocity, therefore an increase in axon diameter would also lead to an increase in conduction velocity.

Neural processes are involved in the stretch-shortening cycle (SSC) or stretch reflex and research has shown that sprint athletes exhibit greater reflex force than endurance athletes. This may be partly due to a combination of genetic determinants but is also a result of training, which affects the reflex response in participants. An increase in muscle strength and the stiffness of the muscle upon loading (the muscle does not lengthen as readily when force is applied to it) increases the SSC, which is beneficial in the sprint process. Elite athletes push off the ground in $80-85 \mathrm{~ms}$ per step whilst average athletes are on the ground for $20-30 \mathrm{~ms}$ longer.

The maturity of the nervous system determines whether or not speed training will assist in speed development. The nervous system is not developed enough to benefit from speed training prior to the first seven or eight years of life. From around age seven to around age 15 is the most important time for utilising the nervous system in the development of speed. (See Chapter 16 for more information on this topic)

It was once believed that an athlete's potential for improving speed performance through training started to decrease from their mid-twenties. This belief held because
most professional speed athletes once sought to retire at this stage of their lives, as very few of them could subsequently make a living out of their sport. It is now evident that athletes can continue to increase speed of movement well into their thirties. Linford Christie and Merlene Ottey both made Olympic Games finals in the track and field 100 m event (a good measure of speed) whilst in their mid-thirties.

This lengthening of the professional life-span of speed athletes is due to the increased ability of the contemporary athlete to make a living from their sport, allowing them to continue to train consistently through their twenties and into their thirties.

The scientific community has come out and stated that the key to an athlete maintaining speed beyond their twenties is that they continue to perform regular speed activities year-round. The statement "USE IT OR LOSE IT" is extremely relevant when talking about speed attributes.

## 3. TECHNIQUE

Some athletes are able to achieve greater relaxation at top running speeds, leading to less muscle co-contraction (both agonist and antagonist muscle groups contracting at similar times during a limb movement). During knee-lift, for example, the sprint athlete wants the hip-flexors to contract with a relaxation of the hamstring and gluteal muscle groups, then vice versa for hip-flexion. This results in less speed inhibition and greater maximal running velocities. This may be an inherent ability at the highest levels of sporting accomplishment. But there is no evidence that this ability cannot be achieved through training.

So one of the factors in athletes continuing to improve their speed, even when other variables have stagnated, may be greater relaxation during sprinting performances. Time spent on the task is very important in relation to this, as it may take years of training to be able to control co-contraction, especially when trying to move limbs at maximal speed.

## 4. ANATOMY

Research has found that success in sprinting may be related to certain anatomical factors. Percentage of body fat, leg strength balance and bodyweight are three factors that have been found to be strong predictors of speed performance and which are influenced by environmental factors such as training and diet. Factors such as leg length, and crural and brachial indexes (measure of foreleg length to thigh length and of forearm length to arm length respectively), are genetically determined. The sprint athlete is typically of average height (at an elite level, male 100 m athletes vary in height from 1.70-1.90m and female athletes from $1.55-1.85 \mathrm{~m}$ ) and has a high crural index. The sprint swimmer demonstrates high standing heights (males from $1.90-2 \mathrm{~m}$ and taller, and females from $1.65-1.80 \mathrm{~m}$ ) and high brachial indexes. The better sprinters demonstrate more balanced muscle strength in their legs (particularly quadriceps to hamstring ratios and quadriceps to quadriceps ratios), and due to the frequent strength and power training undertaken by these athletes they generally demonstrate a well-developed muscular system in both the upper and lower body.

## 5. STRENGTH \& POWER LEVELS

Of all the factors involved in improving speed performance, an athlete's strength and power levels may be the most important. Research has shown that there is a strong relationship between both vertical and rebound jump heights (the latter from a depth of 50 cm ) and maximal running velocity (itself highly correlated to 100 m performance). Strength is even more crucial in the acceleration phase of a sprint performance, a phase of major importance to most athletes, and thus should be a major focus of training. (See Chapter 14 for more information on this topic)

It is in the hip-extensors (hamstrings and gluteals) that the greatest relationship is found between strength/power and sprint performance. It is these muscle groups that are the most important in the vertical jump and the drop jump, and in the maximisation of sprint performance. The faster and more strongly the athlete can extend their hip during each stride, the greater the forward velocity attainable during sprint performance.

Several jumping tests have revealed a correlation with sprint performance. Highspeed alternate-leg bounding and high-speed single-leg hopping have both been
positively correlated with sprint performance over distances of 30 m and 60 m . These two tests rely strongly on strength application during speed movements. Research performed on collegiate athletes indicated a strong relationship between hip strength and sprint speed - as hip strength increased, sprint speed improved.

Due to neural adaptations, the ratio of muscle strength to the cross-sectional area of muscle is greater in sprinters than in endurance athletes. It is well established that the leg muscles of sprinters contain a higher proportion of fast-twitch muscle fibres than those of endurance athletes, and these findings suggest that the strength that can be produced by muscle may depend on its fibre composition. Therefore, muscle containing a high proportion of fast-twitch fibres may be capable of exerting a greater force per unit than muscle composed primarily of slow-twitch fibres.

## 6. THE AVAILABILITY OF ENERGY SUPPLY

One of the factors which limits 100 m performance (and repeated bursts over shorter distances) is the production and utilisation of ATP from the adenosine triphosphatephosphocreatine (ATP-PC) system.

An analogy I use to explain this system is that it is like a bucket, and the goal of specific speed training is to increase both the size of the bucket (increase the ATP-PC stores) and speed up how quickly an athlete can empty the bucket (the faster you can release and use the ATP-PC, the greater the force and speed that can be generated).

The development of power for speed is not only limited by the supply of ATP-PC but also by the ability of a muscle's contractile mechanism to utilise these compounds. Large fast-twitch fibres allow a greater amount of fast contractile tension to occur and thus increase the capacity for high-speed sprinting. Fast-twitch fibres can produce and utilise ATP faster than slow-twitch fibres, so the greater the fast-twitch fibre content in the muscle, the greater the opportunity for sustained power movements to occur (as required in any sprint performance).

Intense training with long-lasting contractions (endurance training) has been shown to induce biochemical changes in both slow-twitch and fast-twitch muscle fibres, leading to an increased resistance to fatigue. Athletes performing in sports which
require explosive movements display a higher incidence of fast-twitch muscle fibres and can execute these movements with a higher degree of mechanical efficiency than athletes with a majority of slow-twitch muscle fibres.

## Coaching Implications

1. It is important that coaches maximise fast-twitch muscle fibre development in an athlete from a young age.
2. Always add speed work ( $90-100 \%$ intensity) to the training program, even during an endurance phase, so that you maintain fast-twitch fibre size and function.
3. If possible, try to modify endurance training to minimise the negative effect on the fast-twitch fibres.
4. Improved eccentric muscle strength directly improves a muscle's SSC, which has a positive effect upon speed of movement.
5. Speed development is a long-term process and can be continually improved upon well into an athlete's thirties.
6. Try to work on relaxation whilst sprinting, as this leads to less co-contraction of opposing muscles and greater speed.
7. A correct sprint technique increases an athlete's speed potential and decreases the potential for injury.
8. Plyometrics training is very beneficial to speed development.
9. The correct conversion of strength to sprint-specific power will result in great gains in speed performance.
10. Regular speed and power training improves an athlete's ATP-PC stores, allowing them to run at $100 \%$ intensity for longer periods.

## Chapter 2:

## THE COMPONENTS OF SPEED

The maximisation of an athlete's speed potential requires a focus on one or more of the following areas:

- reaction time;
- agility;
- acceleration;
- running velocity; and
- deceleration.

This chapter provides an overview of these speed components and their importance to overall speed development.

## 1. REACTION TIME

Reaction time can be defined as "the elapsed interval of time from the presentation of a stimulus to the initiation of a response" (Singer 1980). In conjunction with each other, the reaction time and movement time are known as the response time (see Figure 2a).


Figure 2a. Response time
Reaction time (RT) can be divided into two types:

| 1. | Simple RT | One stimulus | One response |
| :--- | :--- | :--- | :--- |
|  | Example | Starting gun | Jump from blocks |
| 2. | Choice RT | Several stimuli | Several responses |
|  | Example | Tennis serve | Return of serve |

Movement time has two components:

1. Acceleration phase - how quickly an athlete reaches their maximal running velocity.
2. Maximal running velocity - the maximal running velocity attainable by that athlete.

## FACTORS AFFECTING SIMPLE REACTION TIME

Reaction time can be affected by a number of factors, such as the type of stimulus, the amount of practice, the athlete's readiness to respond to the stimulus, and the athlete's kinaesthetic sense.

## Type Of Stimulus

Whilst the visual cue is the dominant stimulus for athletes in the majority of sports, auditory cues also play a major role in the team-sport environment. This is particularly true when an athlete is dealing with an opposing player or with auditory signals from surrounding team-mates. To prepare an athlete for these situations, it is important to use a variety of stimuli during your reaction/speed training sessions. Use of both visual and auditory cues would lead to the best adaptations - for example, use of a ball or hand-signal in conjunction with a verbal command, whistle etc.

## Increased Practice

Reaction time usually improves with increased practice. Therefore, as in speed training, it is important to incorporate this component into the training cycle throughout an annual plan. How much of this training you do and the stimuli you use will all depend on the importance of this component to your sport. It's quite easy to improve this aspect of an athlete's performance with short, specific reaction drills at the start of a speed session, or to use some form of stimulus to send the athletes off on each sprint repetition.

Practice should occur frequently and be performed intensely until the response becomes automatic, as in when you hit a car's brake at a red light.

## Readiness For Response

Prior warning and a short delay between the warning and the actual stimulus presentation leads to an improvement in how an athlete responds to a stimulus. It is
important to improve the athlete's concentration prior to the presence of the given stimulus. The better the athlete's ability to switch on just prior to their expectation of a given stimulus, the better the reaction-time response to that stimulus. To increase an athlete's preparation time, it can be useful to vary the amount of time between the preparation signal and the stimulus. For example, if on a command the athlete has to perform a certain task, vary the length of time between the "Get ready" command and presentation of the stimulus, "Go".

## Kinaesthetic Sense

It has also been shown to be beneficial if the athlete has a good kinaesthetic sense (feeling) of his or her own reaction time. This sense can be developed through drills described later in this book. (See Chapter 7 for more information on this topic)

## FACTORS AFFECTING CHOICE REACTION TIME

When choice reaction time is measured, time increases when the number of stimuli presented and the number of responses from which to select are increased (see Figure 2b).


Figure 2b. Effect of increased numbers of stimulus-response alternatives on choice reaction time
In relation to choice reaction time, there are four major factors that determine how successful the response is to the stimulus:

1. Perception of the stimulus (e.g. seeing the ball).
2. Appreciation of its speed and direction (e.g. speed and direction of the ball).
3. Decision on what response is appropriate (e.g. what you intend to do).
4. Carrying out the response (e.g. chasing after the ball).

The perception of the stimulus takes the longest amount of time and therefore the athlete should be trained to improve their responsiveness to the sports-specific stimuli. In a team-sport example, the athletes may have to respond to several varying visual cues, displayed from different angles or at different speeds. (See Chapter 7 for more information on this topic)

Two other factors that affect choice reaction time are the nature and amount of practice. For a given number of stimulus-response alternatives, the greater the time spent in practice then the shorter the reaction time.

## 2. AGILITY

Agility is the ability to quickly change direction and shift body position. Speed, strength, balance and coordination all contribute to agility. Because of the number of variables that determine agility, it is hard to target just one aspect of it in training or to have a test that is a complete and valid measure of an athlete's agility. If we accept that all of the above physical attributes are required to improve agility, then the coach must target all of them during training.

Speed is important because there is the need to change direction quickly. Strength is important in that the athlete has to be able to quickly decelerate their bodyweight and rapidly reaccelerate it in a different direction, which requires high levels of relative strength (strength-to-weight attributes). Balance and coordination are neural attributes that are best developed through the use of varied skill-training sessions, with the overall aim of improving the athlete's proprioception through the more efficient sensory output of proprioceptors located in all joints and limbs.

The best years during which to develop balance and coordination are those when an individual's nervous system is rapidly adapting to the surrounding environment (approximately through the ages of 6-15 years). Improved balance and coordination can still be attained through training following this time period, but the success will be more limited. The attendance of young athletes of gymnastic or motor skill
development classes will improve their chances of developing good balance and coordination in their formative years.

For developing coordination that will be of maximum benefit in most running sports, a child should be introduced to running drills when they are 6-8 years of age. Because strength is such a major factor in improving sprinting speed and because young athletes do not achieve significant strength improvements until they reach 12-15 years of age, there are minimal benefits to be gained from specifically training sprinting speed. This training time can be utilised to develop high-quality speed and agility technique in these young children.

The inclusion of training devices such as medicine balls, low barriers (such as hurdles), skipping ropes and set movement patterns that the athlete has to follow will all improve the athlete's speed and agility. The warm-up phase of a training session is an ideal time to work on a young athlete's agility, proprioception ability and coordination (hand-eye and feet). (See Chapter 7 \& Chapter 12 for more information on this topic)

## 3. ACCELERATION PHASE

Over short distances ( $5-10 \mathrm{~m}$ ), athletes with high strength levels can excel in acceleration sprints because there is a strong relationship between maximal strength and initial acceleration. Beyond 10 m , technique starts to play a more important role and high strength levels alone are not enough to ensure success - the strong athlete with good technique will beat the strong athlete with poor technique.

For athletes such as tennis players, netballers, and forwards in rugby league, rugby union, soccer etc, only basic sprint technique is required, and the main emphasis should be on getting the athlete as strong and powerful as possible. (See Chapter 14 for more information on this topic) Once the distance to be covered increases (e.g. in relation to basketballers, football centres and wings, hockey players etc), the time spent on maximising sprint technique will reap future rewards regarding the maximal sprinting speeds attainable by these athletes.

Acceleration ability is highly dependent upon strength, in particular strength relative to one's own bodyweight (known as relative strength). By improving an athlete's maximal strength, there will also be an increase in their relative strength (the relationship between maximal strength and relative strength is quite high in the early years of strength training). This alone will have the effect of improving an athlete's acceleration phase. (See Chapter 7 for more information on this topic)

If strength training is combined with power-training methods such as resisted training, assisted training, plyometrics, specific weight-room power-training programs, and sprinting (see Chapters 10, 11, 13, 14 \& 15 respectively for more information on these topics), the athlete will ultimately maximise their chances of reaching their acceleration potential.

## 4. MAXIMAL RUNNING VELOCITY

Maximal running velocity is not the main focus for the majority of athletes when developing speed. Most athletes never get the opportunity to sprint more than $10-40 \mathrm{~m}$ (unless, for example, a break is made in a football code) and even then this does not warrant spending time on developing this aspect of sprinting. This sprint phase is usually reserved for the specialist sprint athlete who has to run $100-400 \mathrm{~m}$ at near to maximal speed.

The development of maximal running speed is largely determined by an athlete's genetic make-up. The combination of an optimal stride length ( $2 \mathrm{~m}+$ ) and high cadence ( 5 strides $/ \mathrm{sec}$ ) is the basic tool needed to develop high levels of maximal running speed ( $12 \mathrm{~m} / \mathrm{sec}$ for males; $11 \mathrm{~m} / \mathrm{sec}$ for females). Another influential factor is the sprint technique of the athlete. The athlete with poor running technique will be unable to reach high running velocities, so emphasis should also be placed upon developing good sprint technique. (See Chapter 7 \& Chapter 11 for more information on this topic)

## SPEED RESERVE

One of the arguments for developing an athlete's top speed is what is known as a speed reserve. The concept is that the athlete with a well-developed top speed can sprint as fast as other athletes but with less effort, thus using less energy to do so. This can become important in a game situation when an athlete may have to repeat such sprint performance many times over the duration of the game. The faster athlete can ultimately use less energy per sprint and will have more speed left (speed reserve) at the end of the game. I believe this to be important only for those athletes for whom speed is an integral part of their role in a sport, such as football wingers, centres etc. (See Chapter 7 for more information on this topic)

## 5. DECELERATION PHASE

In endeavours such as team sports and racquet sports where repeated sprints are required, deceleration can become evident in the latter part of the game when fatigue sets in. In this situation the problem may be less neural fatigue than muscular fatigue, but the outcome will be similar - loss of form and a poor performance may result.

Improved strength and phosphate stores developed through speed and strength training can help to offset the speed decrement that may occur at the end of a long and fast game. Speed training under fatigued conditions improves the body's ability to continue to output the required power to maintain speed performances as fatigue sets in. (See Chapter 7 for more information on this topic)

## Coaching Implications

1. As regular practice is required to improve reaction time, this type of training should be undertaken during all phases of the training year.
2. The perception of the object is the phase of choice reaction time that takes the longest, and so the training of this attribute should focus on having the athlete improve their ability to quickly sight the object in question.
3. Structured agility training should be introduced to an individual from approximately 6 years of age.
4. The improvement of spatial awareness (the awareness of one's body in space) is an important factor in improving a child's agility. This can be achieved by involving a child in gymnastic routines that comprise rolling, turns, tumbling etc.
5. Agility and reaction time drills can easily be added to a warm-up routine. This makes the warm-up fun as well as targeting specific physical attributes every time the athlete warms up.
6. If the athlete is required to sprint greater than 10 m , then technique becomes much more important if a high level of performance is to be maintained.
7. The development of a stable running technique while an athlete is young will be of great benefit to them as they progress through the different growth phases.
8. Acceleration ability is highly related to an athlete's leg and mid-torso strength.
9. Specific speed endurance training is required to minimise deceleration in the speed performance - for example, repeated short sprints of $14 \times 20 \mathrm{~m}$ at $100 \%$ intensity with walk-back recovery.
10. A well-developed top sprint technique will allow an athlete to conserve energy and therefore maintain their efficiency through to the end of a competition or match.

## Chapter 3:

## THE KINEMATICS OF SPRINTING

Before a coach can fully develop an athlete's sprint performance, they need to have a detailed understanding of its technical components and requirements. Kinematics refers to the specific technical elements of this movement. An understanding of sprint kinematics will allow a better informed decision to be made on the technical adjustments that may be needed to improve the sprint technique of an athlete.

## 1. THE SPRINTING STRIDE

There are two main phases of the running stride: the supporting and non-supporting phases of each limb. The supporting phase consists of the braking, amortisation (ground contact) and propulsion phases. The non-supporting phase consists of the rising and falling phases.

The supporting phase starts at touchdown. At ground contact the knee is locked into a position of approximately $170^{\circ}$ and the ankle is stabilised by surrounding muscles in $110^{\circ}$ of plantar-flexion. To minimise the braking effect of ground contact, the optimum landing distance of the foot in front of the centre of gravity needs to be less than 40 cm . A distance greater than this increases horizontal braking forces, decreasing stride length and stride rate. Lower-leg rotational speed indicates the amount of braking that occurs during ground contact. If the lower limb can be moving forwards at a velocity close to zero at ground contact, there will be minimal braking. The ideal technique would be to complete lower-leg extension in sufficient time during the air phase to be able to produce a significant amount of lower-leg flexion speed at touchdown. This results in a reduction in the forward braking force during the initial portion of ground contact, positively influencing the velocity of running and stride length. The body passes over the rigid grounded leg (the amortisation phase) until the point where the ground-reaction forces add horizontal drive to the forward-moving body (the propulsion phase). During take-off, the grounded leg actively extends at both the hip and ankle to launch the athlete into the flying trajectory with a small angle $\left(2-3^{\circ}\right)$. This is to minimise the height of the centre of
gravity from the running position - too high a centre of gravity during the flight phase will lead to excessive braking forces at ground contact during the next stride. After leaving the ground, the athlete actively prepares for a dynamic landing.

Analysis of hip, knee and ankle-joint moments, as part of kinetic analyses (measurement of force through the joints) of sprint performers, has concluded that the hip-extensors produce the greatest muscle moments (a muscle moment indicates the resultant muscle activity and details which muscle groups are dominating the activity). Therefore, to maximise horizontal velocity in both the acceleration and top running velocity phases, it is the hip-extensor muscle groups that must be targeted by resistance training to increase their force output.

The second component of the running stride is the non-supporting phase. The first part of this phase is characterised by the lifting of the centre of gravity to the level of the highest point in the stride trajectory. The second part is characterised by the descent of the centre of gravity and the action of the swinging leg through the amortisation phase. After take-off, the backward-moving leg reaches its maximal extended position whilst the front leg is brought to its optimal flexed position. The back leg then flexes at the knee and starts moving forward toward the downwardmoving front leg.

The knee of the swinging leg should remain flexed during the entire supporting leg amortisation phase, as this will increase the speed with which this limb can be cycled to the front position. Moving forward and downward, the swinging leg's momentum increases the force applied over the supporting leg. As it passes the vertical, the swinging leg starts to move forward and upward. Its ballistic momentum assists in the forward acceleration of the moving body's centre of gravity. To control these actions through the propulsion phase, the athlete should bring the foot of the flexed leg through at the same level as the supporting knee, triggering this action with dorsiflexion of the swinging leg ankle. Sprint acceleration is determined by the relative duration of the support phase, as too much time spent in the amortisation phase will decrease stride rate and stride length, resulting in a slower horizontal velocity.

As an athlete fatigues in the sprint musculature (the hip-flexors in particular), the sprint movement is modified as they attempt to push more off the ground rather than moving rapidly with a clawing-type action. This has the effect of creating an imbalance between front and rear-leg mechanics during the sprint action. This technique deterioration results in a greater ground-contact phase, a shorter stride length, an increased potential for injury of the hamstring muscles (especially during the recovery phase of the sprint stride), and a generally slower maximal running velocity.

Throughout any sprint performance, the athlete's emphasis should be on rapid kneelift (which could be better introduced to the athlete as a rapid lifting of the foot off the ground to a position directly under the gluteal). This should be emphasised during all running sessions, even during any slower work such as run-throughs.

## 2. OPTIMAL STRIDE LENGTH \& STRIDE RATE

Too long a stride length (overstriding) may decrease stride frequency, whilst too great a stride frequency may shorten stride length - both of these conditions can decrease sprinting performance. It has been suggested that stride rate has a more decisive role in maximal sprinting performance than that of stride length.

Optimal values for stride length and stride rate exist for each sprinter. The optimal relationship between these factors for an individual sprinter depends on his/her standing height, leg length, explosiveness of muscular contractions, and speed of limb movement.

Analysis of the men's 100 m at the World Athletics Championships during 1987 and 1991 identified a mean stride length and stride frequency for the top two place-getters in 1987 and the top eight in 1991 (see Figure 3a).

| Mean stride length $(\mathrm{m})$ | $=2.53$ | $(2.38-2.72)$ |
| :--- | :--- | :--- |
| Mean stride frequency (stride $/ \mathrm{sec})$ | $=4.64$ | $(4.23-4.90)$ |

Figure 3a. Mean (and range) of values for stride length and stride frequency of 100 m sprint finalists (number of subjects=10) during the 1987 and 1991 World Athletics Championships

During the 1987 100m final, Ben Johnson and Carl Lewis both achieved a maximal velocity of $11.76 \mathrm{~m} / \mathrm{sec}$. During this phase, Johnson and Lewis were $7-8 \%$ below the maximum reported values for their dominant parameter, that of stride rate (Johnson) and stride length (Lewis). This suggests that maximal values are not required for maximal running speed, but that the optimal combination between stride rate and stride length is the essential factor in sprint success.

In studies where the subjects ran at different speeds, both stride rate and stride length increased with increasing speed. These increases are primarily linear up to $7 \mathrm{~m} / \mathrm{sec}$ whereas at higher speeds there is a smaller increase in stride length and a greater increase in stride rate for a given increase in running velocity. This suggests that to achieve advanced performance, stride rate is the limiting factor that should be addressed during the sprint development phase of an athlete's career.

## 3. KINEMATIC VARIABLES FOR ELITE \& SUB-ELITE ATHLETES

A great deal of research has been undertaken to measure the variables of stride length, stride rate, ground-contact times, and flight times in both elite and sub-elite sprint athletes (see Figure 3b), variables which overlap between these two groups. Groundcontact time and stride rate (as mentioned above) are the two variables where the elite sprint athlete demonstrated superior results to the sub-elite sprint group.

## Ground-contact time (GCT)

| Elite sprinter | $70-80 \mathrm{~ms}$ to 125 ms |
| :--- | :--- |
| Sub-elite sprinter | $95-130 \mathrm{~ms}$ |

Flight time (FT)

| Elite sprinter | $120-140 \mathrm{~ms}$ |
| :--- | :--- |
| Sub-elite sprinter | $104-140 \mathrm{~ms}$ |



Stride length (SL)

| Elite sprinter | $2.00-2.72 \mathrm{~m}$ |
| :--- | :--- |
| Sub-elite sprinter | $2.02-2.49 \mathrm{~m}$ |

Stride rate (SR)

| Elite sprinter | $4.09-4.90 \mathrm{stride} / \mathrm{sec}$ |
| :--- | :--- |
| Sub-elite sprinter | $4.01-4.50 \mathrm{stride} / \mathrm{sec}$ |



Figure 3b. Ground contact times, flight times, stride lengths and stride rates of elite and sub-elite sprint athletes

At maximal running speed, an athlete aims to spend as little time on the ground as possible. Researchers found a significant decrease in support time, with no relationship evident in flight time, as sprint performance increased. An analysis of 1984 Olympic sprint medallists showed that the major difference between first place and the minor places was average stride rate.

## 4. HORIZONTAL VELOCITIES FOR ELITE \& SUB-ELITE ATHLETES

Maximal horizontal velocities for the sub-elite sprint athlete range from 8.44$10 \mathrm{~m} / \mathrm{sec}$, whilst for the elite sprint athlete velocities range from $10-12.05 \mathrm{~m} / \mathrm{sec}$. It is worth noting that the place during a 100 m race where each athlete reaches their maximal running velocity varies considerably. The fastest 10 m segments are reached as early as the 50 m segment and as late as the 80 m segment. This suggests that acceleration rates between elite sprint athletes vary quite considerably. A study of the top place-getters in the 1991 World Athletics Championships' 100m final showed they all reached their maximal 10 m segment at the 80 m mark, followed by minimal deceleration over the final 20 m of the race. The results of this race produced the first, second, fourth and equal-fifth fastest times ever recorded over the 100 m distance, suggesting that for maximal performance times sprint athletes should be attempting to delay reaching their maximal running velocity until late in the race. This is achieved through repeated acceleration training and waiting for maximal running velocity to be reached rather than trying to reach maximum speed as quickly as possible.

## 5. CORRELATION BETWEEN SPRINT VARIABLES

The following correlations have been reported in the sprint-studies literature (see Figure 3c).

| Running velocity and stride rate | 0.69 |
| :--- | :--- |
| Running velocity and stride length | 0.87 (Female) |
|  | 0.53 (Male) |
| Stride rate and stride length | -0.85 |
| 100 m record and velocity | -0.84 |
| 100 m record and stride rate | -0.61 |

Figure 3c. Correlation between selected sprint variables (the closer the value to 1.00 or -1.00 , the better the relationship)

Stride length and leg length have been shown to correlate (value not given) with the velocity of running. It has been suggested that there are two factors that account for $90 \%$ of the variance in running velocity: the braking-phase component of the support phase (the distance the foot is placed forward of the centre of gravity and foot velocity at ground contact) and the duration of the support phase. Sprint acceleration was mostly sensitive to the relative duration of the support phase. A significant decrease in support time (GCT) has been shown (value not given) as sprinting performance improved.

The greatest kinematic factor dictating success in sprinting is the maximal horizontal velocity that an individual is able to achieve. However, a high level of maximal running velocity is a precondition, not a guarantee, of excellent sprint performances. A study by Moravec (1988) detailed that several athletes reached a maximal running velocity of greater than $11 \mathrm{~m} / \mathrm{sec}$ but were not able to better sub-elite sprint times ( 10.50 sec ) over the 100 m distance.

## 6. MECHANICAL EFFICIENCY IN SPRINTING

The mechanical efficiency of sprinting decreases with an increase in running speed. This has been determined by taking into account athletes' total oxygen uptake divided into the calculated external and internal mechanical work (from data obtained from force platforms and high-speed film). This is why excellent technique in combination with relaxed sprint movements will lead to the best sprint results.

Another area of importance in sprinting is that of the ankle and how, as an athlete, you prepare your ankle for the ground-contact phase of each stride. A decrease in the ground-contact time is required to increase running speed. This can be achieved by preparing the ankle for ground contact prior to the contact phase. This pre-tensing of the ankle joint improves the use of the elastic strength present in the Achilles tendon and calf musculature.

The pre-tension of the ankle should occur immediately following the take-off phase. The ankle should be immediately placed in a cocked (dorsi-flexed) position, improving the contractility of the gastrocnemius, which aids in bringing the heel quickly up to and under the gluteal (as well as over the knee of the contralateral grounded limb). This cocked position is maintained through the non-support phase to the point at, and following, the ground-contact phase.

Because of the increased stiffness in the ankle, the stretch-shortening cycle (SSC) in the Achilles tendon is improved, leading to high forces being produced through this joint. The activation of the SSC increases power output as the athlete begins to push off from each take-off leg. Also, in mechanical terms, if the ankle is pre-tensed then there is less collapse through the ankle-joint at ground-contact time and so less time is spent in collapse/recovery mode, effectively decreasing the ground-contact time with each ground contact.

Ankle pre-tension cues should be developed through the use of speed and coordination drills and should be a focal point of training until the athlete develops the motor program to ensure the position becomes automated. (See Chapter 12 for more information on this topic)

As a side-benefit of improving running speed, an increase in ankle stiffness has a positive effect upon agility. One of the limiting factors in agility is the ability to quickly brace one leg whilst changing direction. Improved ankle stiffness leads to better bracing of the grounded leg, therefore decreasing the time needed to change direction. This is obviously beneficial to athletes in sports with an agility component, e.g. basketball, netball, hockey, tennis, squash, badminton etc.

## Coaching Implications

1. The less distance that an athlete's foot moves in front of their centre of gravity with each step, the less are the braking forces applied to the ground and the faster the athlete should be able to run.
2. The vertical forces in sprinting are greater than the horizontal ones, which means the athlete has to be very strong to be able to minimise collapse of the centre of gravity with each ground contact.
3. The stronger the athlete is in the ankle-flexors, knee and hip-extensors, the less the collapse at the point of foot contact, leading to decreased ground-contact time and increased running velocity.
4. The foot of the recovery leg should pass about equal with the knee of the support leg.
5. Efficient front-side mechanics (knee-lift) improves acceleration and decreases the stress placed upon the hamstring muscle groups.
6. The optimal stride rate and stride length is not the maximum possible of each - it is the best combination of the two attributes which leads to ultimate speed success (this combination is dependant upon the athlete's attributes).
7. The main difference between elite and sub-elite sprint athletes is in cadence (stride rate) and this should therefore be a major focus of training year-round.
8. Most athletes overstride trying to offset the lack of stride rate. Sprint programs should emphasise maximising stride rate through fast leg-turnover drills and good technique.
9. The more efficient an athlete's sprint technique, the less energy is required to sprint, therefore the more energy the athlete has to continue to sprint at high intensity at the end of a match or competition.
10. Ankle pre-tension drills will help decrease ground-contact time and increase speed and agility in players.

## Chapter 4:

## THE IMPORTANCE OF RECOVERY TO SPEED DEVELOPMENT

One of the major limitations in any training program is how quickly an athlete can recover from a training session. The physical demands placed upon an athlete when performing speed training are high due to the intensity of such training (usually $90 \%+$ ). High-intensity training causes the most disturbances in the body's homeostasis (balance) and therefore recovery takes longer after this type of physical activity. The coach who can incorporate appropriate recovery strategies into training regimes will be giving their athletes the best chance of maximising gains in speed and power development.

## 1. NEURAL VS MUSCULAR FATIGUE

Unlike many other physical capacities, sprinting is not seen to create high levels of fatigue due to both the short nature of the training and the lack of visible fatigue experienced by anyone training for this ability. The fatigue that is evident is that of a specific neural nature, a decrease in the efficiency of the nervous system in continuing to allow the body to perform the activity at hand with the same level of skill or speed. Along with this neural fatigue comes the muscular damage that occurs from having an athlete perform maximal muscle contractions at speed through varied distances and movements. This type of fatigue is different to the energy-store depletion that occurs in all distance athletes (runners, cyclists, swimmers, rowers etc) through their high-volume training.

What is not recognised widely is that speed and power athletes require as much recovery time and use of recovery techniques as endurance athletes. It has been acknowledged that the central nervous system is the "seat of fatigue".

The central nervous system can take up to seven times longer to recover from training than the muscular system. This means that to effectively perform speed work two to three times per week, an athlete must use techniques that ensure adequate recovery between sessions throughout the training week.

## 2. RECOVERY TECHNIQUES

Recovery techniques can be classified under several headings:

1. Manual recovery techniques, such as massage, submaximal aerobic activity, and stretching.
2. Physiotherapeutic recovery techniques, using spas, saunas, pools, steam rooms, flotation tanks, and hyperbaric chambers.
3. Nutritional recovery techniques, such as fluid and electrolyte replacement, and correct nutritional intake during and after training.
4. Lifestyle recovery techniques, such as sleeping well, an unstressed lifestyle, and balanced training-recovery workloads.

## MANUAL RECOVERY TECHNIQUES

Massage (in the many forms available) is quickly establishing itself as an effective way of improving the rate of recovery of athletes in a variety of sports. Massage can be used in the development of speed in several ways.

Firstly, for an athlete to be ready for a sprint session, they must be fully prepared for maximalspeed muscular contractions. This preparation can be enhanced by undergoing a light massage prior to the speed session, to ensure that the athlete has the correct muscle tone throughout the muscle groups that are going to be stressed during the activity (e.g. hamstrings, quadriceps and calf muscles). Correct muscle tone is a muscle tenseness that is not too hard or too soft. Most importantly, massage can reveal any areas of specific tightness that may create a muscle imbalance during maximal sprinting, potentially leading to a muscle tear. Athletes may have an area of tightness that traditional warm-up and stretching cannot target, so a light massage in this area can achieve the correct muscle preparation.

After a speed, power or strength training session, the athlete may have an overall feeling of tightness from repeated maximal muscle contractions. Over the next 24 to 48 hours the rate of neuromuscular recovery can be enhanced through the use of several massage techniques, such as effleurage and petrissage. These can improve an athlete's well-being and speed up the recovery process prior to the next training session. Whilst access to a masseur may be limited, there are basic massage techniques that the coach and athlete can learn to allow treatment at any time during any training week. There are several good instructional books on massage which refer to both sports massage and self-massage techniques, and purchase of these books would be well worth the money (see Bibliography for books by Clews, Phaigh \& Perry, and West).

Other methods of manual recovery, such as submaximal aerobic activity (jogging, cycling, swimming) and stretching, can be performed during and after (warm-down) the training session, and on days when the athlete does not have structured training.

Between training elements, it can be beneficial for the athlete to perform stretching exercises to ensure the muscle groups being used remain flexible (this is especially important when
performing maximal speed runs, which can tighten up hamstrings, quadriceps etc). (See Chapter

## 6 for more information on this topic)

Stretching brings muscles back to their resting lengths - muscles remain in a contracted state after exercise, which decreases blood flow and impedes the removal of waste products. It also improves long-term range of motion around the joints specific to the sprint activity, which is important as muscles that are more flexible are less prone to injury and allow greater force production through a larger range of motion, desirable in sprint activities.

By performing a light jog or a series of relaxed run-throughs after a training session, the athlete is increasing blood circulation to the muscles, removing any waste products, and allowing themselves to psychologically come back to a basal level after the training session.

Stretching and light aerobic activity can also be performed between the days of speed training. Many of my athletes perform tempo training sessions, which involve repeated submaximal runthroughs at $60-75 \%$ of maximal speed over $50-100 \mathrm{~m}$ (e.g. $6-10 \times 100 \mathrm{~m}$ with a 50 m walk between) followed by relaxed stretching. This type of activity improves the recovery ability of an athlete whilst maintaining aerobic fitness and controlling body fat levels, and allows the athlete to concentrate on improving flexibility after the running component is finished.

## PHYSIOTHERAPEUTIC RECOVERY TECHNIQUES

A vast array of scientific studies has been carried out over the past 30 years to determine ways of improving the recovery process of athletes, and much of this research has been aimed at the use of physiotherapeutic techniques, utilising spas, saunas, pools, steam rooms, flotation tanks and, just recently, hyperbaric chambers. For all but the elite few, the last two methods are not within practical use. But the first four methods are relatively easy to access in the numerous health clubs that are present across the country.

The hydrotherapy spa (one that is equipped with pressure jets) can be a great means of increasing recovery ability in speed and power athletes, as it can usually be used as an alternative to massage (the tight muscle group is placed directly in front of the jet stream). Also, because of the stimulating effect of the hot water, mineral salts and high-pressure water jets, the athlete's circulation is increased (assisting in waste-product removal and improved tissue regeneration), central nervous system activity is decreased, and psychologically the athlete winds down, which all leads to total restoration. The spa environment is also one that is conducive to improving flexibility. The athlete could perform their stretching routine whilst in this hot, relaxing environment. As time in a spa can cause athletes to become lethargic, any attempt to perform quality training following these sessions would lead to minimal benefits.

The second recovery method that is readily available in any health club is that of the sauna. These devices allow for a dry heat to be generated, and it is possible for an individual to remain in one of these rooms at quite high temperatures $\left(50^{\circ}+\right)$. The main benefit of this recovery method is that it will increase the circulation of blood to an athlete's outer muscles and skin. It will also improve the transportation of nutrients to the muscles, as well as the removal of waste products from the same muscle groups. This environment, like that of the spa, will also decrease psychological tension and stress, and is a good modality to use following a training session.

In combination with a sauna, an athlete can also use a plunge pool or regular pool that is filled with water at room temperature. Russian researchers studied the benefits of alternating hot and cold environments on the human body and found that with the correct alternation there was a raised level of recovery taking place in athletes who used this method. A commonly used protocol is $2-5 \mathrm{~min}$ in the spa/sauna followed by $1-2 \mathrm{~min}$ in the plunge pool.

An alternative to saunas and plunge pools is the regular shower, where good results can be achieved if the athlete alternates hot and cold bursts of water. The best ratio of hot to cold is $60-$ 120 sec of hot water followed by $30-60 \mathrm{sec}$ of cold water (as cold as you can stand).

Another recovery device is the steam room (sometimes called a Turkish bath). These can be found in certain health clubs and are similar to a sauna except that there is a constant supply of water being sprayed into the air, creating a climate with $100 \%$ humidity. The response of the body to this environment is similar to that which occurs in the sauna, except that in this climate the body is not efficient at removing excess body heat and so time spent in this climate should be short ( $5-10 \mathrm{~min}$ per session). The physiological responses to this environment are also similar to those which occur in the sauna, with increased peripheral circulation and decreased neural and psychological activity.

Flotation tanks are rarely available to anyone excepting Australia's elite athletes, but there are benefits to be had if access to this modality can be found. These tanks are half-filled with a very high concentration of salt water which allows the athlete's body to float without any limb movement. The athlete enters the tank and lies on their back in the salty water; then the lid is closed, leaving the athlete in a dark and nearly soundproof environment. The athlete can now totally relax, with no body part touching a solid surface. The added advantage of these tanks is that an athlete's favourite music can be played to them whilst they are relaxing, or an appropriate video can be viewed. This modality works well in conjunction with psychological training techniques, for example where the athlete is completely shut off from all external stimuli and can concentrate on skills tests that have been set by a sports psychologist.

A recent advancement in recovery techniques is the hyperbaric chamber, which is commonly used by scuba-divers who are suffering from the bends (or decompression sickness). It is possible to increase the air pressure inside these chambers, thereby increasing the concentration of oxygen inside an athlete's body. After inspiration, the concentration of oxygen drops rapidly as it reaches the muscles in the limbs. This modality increases the supply of oxygen to the required muscles, therefore increasing the recovery process at the cellular level. Like the flotation tank, this modality is currently only readily available to Australia's elite athletes.

## NUTRITIONAL RECOVERY TECHNIQUES

During a training session (which in some sports may last up to $3-4 \mathrm{hrs}$ ), it is vital that the athlete does not become dehydrated, as a body in a dehydrated state will be less able to perform the quality skill or speed movements required in sprint training. Also, fatigue will set in earlier, as the body has to work much harder to supply the required energy when the body is in a dehydrated state. The reason for this is that as the athlete becomes increasingly dehydrated, blood volume decreases leading to greater viscosity (thickness) of the blood, making it harder for the heart to pump the blood around. Less blood being pumped around the body means less oxygen getting to the muscles, and so fatigue can set in earlier. Also, increased sweating leads to the loss of salt, which is involved in maximising muscle contraction. The muscle contraction mechanism becomes less efficient and the chance of muscle cramping and subsequently major muscle tears is increased.

It is therefore vital during any training session that an athlete be given time to replenish body fluid. This should occur approximately every $10-20 \mathrm{~min}$ depending on the activity the athlete is performing and the current environmental conditions. The hotter and more humid the conditions, the more frequently fluid replacement should occur.

Whilst the replacement of fluid by drinking water is okay, the whole recovery process can be improved through the intake of a weak carbohydrate (and electrolyte) solution - this enhances gastric emptying (speeds up the process of fluid and nutrients being emptied from the stomach and intestines and relayed to the muscles). There are many such supplements currently available on the market, including Exceed, Sports Plus and PowerAde. In these products, the nutrients have already been mixed into a liquid in the correct concentration (which should be less than $10 \%$ of nutrients to liquid) for maximal absorption. It is also possible to buy these supplements in powder form and mix up the drinks yourself. It is very important that the concentration does not exceed $10 \%$, otherwise there will be delayed gastric emptying and increased dehydration may occur. Work has also been done on the use of fruit cordials in diluted form, and it was shown that this mixture is a good substitute for the many commercial brand-name products.

Fluid replacement can be complemented by the intake of fruit during training. If the athlete is involved in long training sessions, the consumption of bananas, oranges, apples etc can perform a similar role to that of the drink supplements. However, the eating of solids is only really possible if the athlete is not performing heavy endurance-type work, as a full stomach is not conducive to quality training. During speed work, where there is plenty of rest between repetitions, the athlete can ingest these types of solids with only minimal discomfort during training as a consequence.

If athletes are not used to consuming fluid or food during training, it will take some time for them to become accustomed to this process. But the long-term rewards gained from such training practices will far outweigh the initial discomfort.

## LIFESTYLE RECOVERY TECHNIQUES

All of the previously mentioned recovery processes should be seen as additions to the primary set of techniques, the lifestyle recovery processes. These include getting a good night's sleep, ensuring enough recovery days are interspersed throughout the training days, instituting a recovery week during any training month, and allocating a recovery month(s) during any training year. Also, the less stress faced by the athlete outside of training (external stress), the faster their rate of recovery between sessions.

One of the best recovery techniques is that of sleeping. Most hard-training athletes require 810 hrs of sleep per night. For the serious athlete, it is imperative that they get this amount of sleep every night. It is quite disadvantageous for the athlete to go out to all hours of the morning and then rock up to training with only a couple of hours sleep behind them. They will not be able to perform to their potential and therefore will have wasted a training session (also an opportunity to take a further step towards success), not to mention the coach's time!

Stress can develop in a variety of situations, such as work, school, study, family and relationships. Environmental factors can also lead to stress (poor weather during training, early morning starts etc). The less external stress the athlete is placed under, the better will be their adaptation to the training processes they are undertaking. As a coach you will have limited control over many of these factors, but you may have to act as a go-between for the athlete when dealing with parents, work or school. You may be called upon to explain why the athlete is required to train so much, and ask that they be given some concessions to ensure they can handle all the pressures currently being placed upon them.

## 3. THE SUPER-COMPENSATION PROCESS

Effective progressive overload and super-compensation can only come about if the athlete's body is given time to recover from the stresses placed upon it from any bout of training. Progressive overload is the process whereby as the athlete adapts to training there is a continual increase in the volume and intensity of training. This process cannot involve a linear increase as this would lead to rapid overtraining and possible injury. It is through the process of recovery that the athlete's body is able to make the appropriate changes for it to handle more work at a later time.

The process of adapting to any training bout is known as super-compensation (see Figure 4a). When the body is exposed to a certain stimulus, some damage occurs to the muscles, tendons, ligaments, joints, bones etc. Soon after (the sooner the better), the body will begin the rebuilding process. There is an increase in connective tissue and muscle being laid down to try to minimise the potential subsequent stress placed upon it. If this process is continued through the correct sequence of training and recovery, the body will become stronger, bigger, fitter or faster.


Figure 4a. Super-compensation, or adaptation to the physical stress of training
If an athlete is given enough time to recover between training sessions, their body will go through a super-compensation peak. For a short time (2-5 days) the body will be in a stronger, fitter state than it was prior to the exercise bout. The ideal time to re-expose the body to a training stimulus is during this time. It is through the concept of periodisation that the coach and athlete can predict these peaks and adjust the training schedule accordingly. (See Chapter 15 for more information on this topic)

Use of the correct recovery processes will lead to a decrease in the time taken to reach the next super-compensated level (see Figure 4b), therefore increasing the amount of work done over time and also the rate at which the athlete reaches the physiological state required for high-level performance.


For example, from the above graph you can see that after the correct recovery methods are added to the training schedule, Athlete $A$ is able to perform more work and has a greater adaptation over the same time as compared to Athlete B.

A frequently asked question is how long does it take for an athlete to recover from a single training bout. This is a very difficult question to answer. The time taken to reach a supercompensation peak will depend upon factors such as training background, recovery processes used, training elements performed, the sex of the athlete, and the maturity level of the athlete. Generally, the more conditioned the athlete, the faster they will adapt to certain training stimuli. Younger athletes (8-20 years of age) recover faster from training than older athletes do, but older athletes have more experience in handling stress and this can offset the limitation on how quickly they recover.

The time required to recover from certain training elements is generally regarded to be as follows:

- Speed, skill and power training 2-4 days between maximal sessions.
- Strength training 2-3 days between sessions.
- Speed endurance training 3-5 days between maximal sessions.
- General endurance training 1-2 days between sessions.
- Flexibility
$12-24 \mathrm{hrs}$ between sessions.

Using the above list as a guide, here is an example of a weekly training session for an advanced athlete (see Figure 4c), including speed, skill and strength components.

| MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY | SATURDAY | SUNDAY |
| :---: | :---: | :--- | :--- | :--- | :--- | :---: |
| Speed | Skill | Speed | Skill | Recovery | Recovery | Game |


| Weights | Recovery | Endurance | Weights | Skill | Rest | Recovery |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |

Figure 4c. Sample weekly training session for the advanced athlete
And here is an example of a weekly training session for a beginner athlete (see Figure 4d), including skill, weights and fitness components.

| MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY | SATURDAY | SUNDAY |
| :---: | :---: | :--- | :---: | :---: | :---: | :--- |
| Rest | Rest | Weights | Rest | Rest | Rest | Game |
| Weights | Skill/ <br> Fitness | Rest | Skill/ <br> Fitness | Weights | Rest | Recovery |
|  |  |  |  |  |  |  |

Figure 4d. Sample weekly training session for the beginner athlete
The amount of time between sessions will be totally dependent upon how quickly the athlete recovers from certain training elements. Some athletes recover faster from strength training than from speed, and vice versa.

## Coaching Implications

1. Through the correct use of recovery techniques, it is possible to get more of the appropriate training completed within a given timeframe - this is one of the keys to greater performance by an athlete.
2. Neural fatigue is not easily detected in athletes. Indicators of neural fatigue include lethargy, a decrease in skill acquisition, and possibly a change in mood.
3. Massage is an excellent method of recovery for speed and power athletes. High-intensity training leads to tight muscles and massage is a great way of relieving tight areas in muscle tissue.
4. A quality warm-down after any training session will help the body's natural recovery process. The warm-down should be a combination of light aerobic exercise (e.g. slow jog) and 5-10min of static stretching exercises.
5. The use of spas, saunas, pools, steam rooms, flotation tanks and hyperbaric chambers can speed up the recovery process in athletes.
6. Recovery can be accelerated using the regular shower. By alternating bursts of hot and cold water, the nervous system is stimulated, blood flow is increased, and waste products are more quickly removed from muscle tissue.
7. Athletes should be introduced to fluid replacement from an early training stage. Fluid uptake every $15-20 \mathrm{~min}$ ensures that an athlete does not become dehydrated, which will have a negative effect on performance.
8. Minimising stress and maximising sleep are two of the best lifestyle recovery approaches that can be used by an athlete.
9. The correct combination of work and rest (known as progressive overload and supercompensation) will ensure an athlete does not get injured through overtraining.
10. Recovery techniques should be used during each day of the training cycle. The more these techniques are integrated into training, the better the chance an athlete has of reaching their potential with minimal injury.

## Chapter 5:

## TRAINING COMPONENTS

For a coach to maximise their athletes' speed potential, they need to have a good understanding of the physical attributes involved in the sprint process and how these affect performance. This chapter will address the most important sprint attributes (strength, power, endurance and flexibility) and explain why the correct development of each of these physical traits will help to maximise your athletes' running speed.


## 1. STRENGTH \& POWER

As detailed in Chapter 2 (The Components of Speed), two of the major factors that determine success in sprinting events are an athlete's ability to accelerate quickly and their ability to achieve a high running velocity. The greater the level of force (strength) and the faster that force can be applied (speed strength, or power) to the ground with each stride, the greater the enhancement of these capacities.

There is a major difference between the strength requirements of the acceleration phase and those of the maximal running velocity phase. This difference is in the time spent on the ground with each ground contact and the force-generation capabilities of
muscle over time. Ground-contact times during the acceleration phase can be greater than $200 \mathrm{~ms}(0.2 \mathrm{sec})$ whilst at top speed values are as low as $70 \mathrm{~ms}(0.07 \mathrm{sec})$. Musclecontraction strength is governed by what are known as force-time characteristics (see Figure 5a).


Figure 5a. Force-time curve
The force exerted by the muscle is greater when the contraction time is longer, since time is required for tension to be created by the muscle's contractile components. During the acceleration phase, where the ground-contact time of each stride is around $200 \mathrm{~ms}+$, the athlete can use a greater percentage of their muscles' strength capacity. At maximal running velocity (ground-contact time of 100 ms ), only a small portion of the athlete's muscle strength can be exerted each ground contact.

A sprinter has to be able to produce high muscle forces quickly, to ensure sufficient external force generation despite the relatively short ground-contact times. Elite sprint athletes have demonstrated greater force production with each ground contact, with less time on the ground, than sub-elite sprint athletes (see Figure 5b). This suggests that strength is very important in sprinting.

(Kg)


There are four major strength attributes that are used in a sprint performance:

1. Maximal Strength - The maximal amount of force a muscle can apply to a movement.

Use: To minimise collapse during the ground-contact phase of each sprint.
2. Starting Strength - The ability to apply a great force in the initial milliseconds of the movement.

Use: To explode from a stationary position (overcome bodyweight quickly).
3. Explosive Strength - The ability to contract the muscles quickly, with force, throughout the range required in the sporting movement.
Use: To continue to accelerate rapidly following the initial explosive take-off movement.
4. Reactive Strength - A muscle's ability to utilise the stretch-shortening cycle (SSC) during a fast movement.

Use: To minimise the ground-contact time with each foot contact and to maximise force output at speed.

The above attributes are all used at different times throughout a sprint performance. Maximal strength assists starting strength and explosive strength (good for initial acceleration), and reactive strength then becomes more important during the maximal running velocity phase. Reactive strength is best developed through regular plyometrics training. (See Chapter 13 for more information on this topic)

## ACCELERATION \& STRENGTH

The moment a sprint athlete initiates a sprint (e.g. leaves the starting blocks), the velocity of the athlete's centre of gravity is approximately $3.5-4 \mathrm{~m} / \mathrm{sec}$. By the third and fourth stride, the velocity of the centre of gravity has increased by a further
$1 \mathrm{~m} / \mathrm{sec}$. It has been shown that there is a high correlation (0.66) between force production in the propulsion phase and running velocity, emphasising the importance of maximum strength during the acceleration phase of sprinting.

There is also a high correlation between force production in sprint starting and overall performance. This relationship between start velocity and 100 m running time performance implies a direct link between the start (strength and power to overcome the body's inertia) and total sprint performance.

## MAXIMAL RUNNING VELOCITY \& STRENGTH

The main source of force production during sprinting is the work done to combat the gravitational and ground reaction forces that occur during the support phase. During the maximal running velocity support phase, the vertical fall generated during the descent from the flight phase must be reversed. Also, decreased horizontal velocity due to braking must be regenerated. Maximal strength will limit collapse in the support phase and lead to utilisation of the athlete's reactive strength (a strength which allows an athlete to efficiently move from an eccentric contraction to a concentric contraction) from the eccentric phase to the concentric propulsion phase.

For all but elite sprint athletes, maximal running velocity can be reached and maintained only for somewhere between $40-60 \mathrm{~m}(5-7 \mathrm{sec})$. This is due to several factors, including neural fatigue, substrate depletion (Adenosine TriphosphatePhosphocreatine, or ATP-PC), air resistance, and an increase in stride length (increasing braking forces) to compensate for the decrease in stride rate that occurs as the athlete fatigues. To sustain a maximal sprint performance beyond $5-7 \mathrm{sec}$ requires high strength levels, to offset the increasing braking forces that can occur with increased stride length. The increased ATP-PC stores that result from strength training can help maintain an athlete's power output for longer, therefore reducing the total deceleration phase that will occur in the final stages of any sprint race - or in the case of a team-sport athlete, minimise the extent to which they slow down in the latter stages of a game.

## GROUND-CONTACT FORCES

The higher the athlete's maximal running velocity, the greater the vertical impulse (impulse $=$ force x time) at these higher horizontal velocities. This results in athletes of high calibre requiring great strength levels - especially in the hips, knees and ankle-joints - to continue to resist increasing gravitational forces as running velocity increases.

It has been demonstrated that the SSC capacity of the lower limbs is greater in elite male sprinter athletes than in sub-elite male sprinter athletes, and is determined by the smaller descent of the centre of gravity during the eccentric phase.

The elite sprinter decreases ground-contact time (which increases stride rate) without affecting the other performance results (e.g. stride length) by having greater leg strength. As running speed increases, both horizontal and vertical eccentric forces increase, thereby requiring greater strength levels to combat these (see Figure 5c).

| Eccentric (Braking) Phase | Maximal Run | Supramaximal Run |
| :--- | :--- | :--- |
|  |  |  |
| Horizontal Maximum (N) | $880 \pm 147$ | $1052 \pm 157$ |
|  | $445 \pm 72$ | $559 \pm 104$ |
| Vertical Maximum (N) | $2704 \pm 282$ | $3481 \pm 646$ |
|  | $1707 \pm 285$ | $2044 \pm 352$ |
|  |  |  |
| Concentric (Driving) Phase |  |  |
|  |  | $599 \pm 65$ |
| Horizontal Maximum (N) | $595 \pm 76$ | $334 \pm 52$ |
|  | $312 \pm 35$ | $2294 \pm 236$ |
| Vertical Maximum (N) | $2356 \pm 206$ | $621 \pm 104$ |

Figure 5c. Ground-contact forces ( $N$ ) recorded in both the eccentric and concentric phases during maximal and supramaximal (overspeed) sprinting

The above table shows that as the sprint athlete increases their running velocity, ground forces also increase - especially in the eccentric vertical direction, which is where high strength levels can offset this potential limiter of performance.

Elite sprint athletes have demonstrated that they minimise their ground-contact times by properly preparing the ground leg for touchdown and by developing sufficient leg strength to generate the necessary velocity changes during this short ground-contact time.

When looking at Australia's best sprint athletes, it is clear that the top-level 100 m athletes also produce the best bounding results, whilst many of the 200 m sprint athletes do not display the required power outputs (as measured by set bounding test protocols) to excel at the 100 m distance.

## THE RELATIONSHIP BETWEEN STRENGTH \& OVERALL SPRINT PERFORMANCE

Researchers have found significant differences between the sexes regarding stride length, but not stride frequency. This discovery emphasises the importance of strength in sprinting, as male sprinters are both stronger in all lower-limb joints tested both concentrically and eccentrically, and are also on average faster than female sprinters. It has been noted that for the sprints, the major performance-inhibitor for the female athlete was lack of leg strength, especially in the hamstring group. It has been demonstrated that 100 m sprinters with times of $10.62 \pm 0.04 \mathrm{sec}$ produced greater forces (both concentrically and eccentrically) with less contact time than sprinters with times of $10.96 \pm 0.19 \mathrm{sec}$.

## THE IMPORTANCE OF EXTENSOR MUSCLE GROUPS TO SPRINTING

It is the strength around the hip-joint that is directly related to performance in sprint events, with particular attention drawn to the strength in the hip-extensor muscles (hamstrings and gluteals). The hip-extensor muscles are important in minimising the braking forces generated at ground contact by forcefully contracting prior to ground contact. This will minimise the touchdown distance from the centre of gravity and will assist in pulling the body over the touchdown point during the initial portion of the support phase and into the propulsion phase.

This hamstring muscle action is an important limiting factor in sprinting due to the eccentric loading placed upon the muscle group prior to and immediately following
ground contact. Eccentric muscle conditioning has been suggested as a means of achieving enhanced performance.

Elite sprint-trained athletes demonstrate a superior hip-extension and hip-flexion ratio at high testing speeds compared with those of untrained subjects. This indicates that the extensor muscles retain higher relative strength at the faster movement speeds. This may be due to the increased capacity of the muscle to store elastic energy that is subsequently used in the concentric phase of force production. This finding may be related to the functional training of elite sprinters who spend much of their training time performing high-speed hip-extension movements that mimic the motions seen during push-off in sprinting.

## THE IMPORTANCE OF FLEXOR MUSCLE GROUPS TO SPRINTING

An alternative view of sprint performance is held by many researchers and top sprint coaches who believe that it is the hip-flexors (psoas major, pectineus, tensor fascia latae and rectus femoris) which are the muscle groups controlling superior sprint performance. These researchers and coaches suggest that the higher the forward acceleration of the thigh (controlled by the hip-flexors), the higher the stride rate and the shorter the length of the ground-contact phase.

It has been suggested that the greater the speed of knee-flexion at the point of ground contact (of the opposing leg) in conjunction with hip-extension, the less the forward horizontal velocity of the pre-grounded foot, therefore decreasing the braking forces that develop at ground contact during each stride.

## 2. SPEED ENDURANCE

Speed endurance is the ability to perform rapid movements repeatedly over time. This type of endurance refers to movements performed near to or at $100 \%$ capacity. This performance attribute is required in most speed sports, e.g. in regard to the team-sport athlete who has to repeatedly sprint after the ball or another opponent, or who has to quickly get back into their position. The individual-sport athlete such as the tennis player must be fast for up to four hours; the sprint athlete must be able to maintain
maximal running speed over distances of $100-400 \mathrm{~m}$. Even the distance athlete (runner, swimmer, cyclist) must be able to reach a high speed for surges during their event, and in the sprint for the finish.

It is very important to note that athletes who undertake frequent submaximal sprint performances are conditioning themselves to sprint submaximally, and will not be able to perform repeated maximal sprints if required.

Unlike traditional endurance training which would be performed at the end of any training session, the development of speed endurance, like the development of speed, requires the athlete to be relatively fresh. This training element should be performed at the beginning of the training session, or following low-intensity and low-volume work. It would be appropriate to perform drills, skills and other light training components prior to this work.

This work is different from the traditional fitness training whereby the athlete quickly fatigues, leading to slower and slower performances over the set distances. With speed endurance training, it is vital that the athlete maintains a high running speed. As soon as the athlete begins to tire significantly (their times get slower), the athlete will not be training the same energy system (they are moving more to the aerobic system rather than taxing the anaerobic system) and the training set should be terminated. Unless the athlete can recover enough to continue at the required speed, that is effectively the end of the speed-endurance session.

Too often a sports coach makes an athlete begin a session with speed work, but due to the lack of recovery between sets the session quickly becomes a speed-endurance session. If this regime is continued, the athlete will quickly become so fatigued that the aerobic energy system will play a major role in energy supply. It is not a sound training principle to go from speed work to aerobic work in the same session.

At no time would I recommend sprinting distances over 100 m . The traditional 200500 m repetitions performed "flat out" do little to prepare the team-sport athlete for the demands of the game. The team-sport athlete will never have to run over 100 m in a game, and rarely will run more than 40 m (netballers never more than 15 m , basketballers 30 m ). These distances come under the component of speed known as
acceleration - the physical requirement to accelerate is different to that of developing maximal running velocity. (See Chapter 7 for more information on this topic) The team-sport athlete required to sprint $100-500 \mathrm{~m}$ would therefore be training for physical abilities rarely used in their sport. Additionally, running over these great distances is very foreign to them, and performances will inevitably be of lower quality than required.

To make this type of training very specific in terms of the sport and the athlete's physiology, it is infinitely better to have the athlete perform repeat sprints over distances of $10-60 \mathrm{~m}$, depending on the sport. This requires the athlete to accelerate and decelerate, then to reaccelerate as in a game situation. It is much harder to have to continue to reaccelerate the body than to continue at a constant speed. Also, the athlete can clearly see the finish line for each repetition and will be in a better position psychologically to run harder. Best of all, the coach can stand very close to their athletes at all times, giving encouragement and instructions for them to perform each repetition at the required speed.

Physiologically, the body adapts to speed-endurance training in the following ways:

1. The body improves its tolerance to lactic acid production (muscle by-product from maximal work over prolonged periods). This tolerance comes about by:

- the more efficient removal of the lactic acid;
- the degradation of the lactic acid before it can leave its site of production; and
- an improved buffer to lactic acid (the body produces bicarbonate ions which are alkaline and these neutralise the lactic acid they encounter).

2. The cellular process for producing ATP is less inhibited by lactic acid through regular exposure of this system to lactic acid. This allows the ATP-producing system to continue to produce the required energy, even with lactic acid present in the system.

## 3. FLEXIBILITY

For an athlete to improve their sprinting ability, they must be capable of performing very fast limb movements through large ranges of motion. The sprint athlete is
required to cycle their legs through a large range at speeds of up to 5 strides per second, and this is only achievable with well-developed hip and leg flexibility.

Many sprint faults are caused by an athlete's lack of flexibility in either the hip-flexor or hamstring regions. Tightness in either of these areas increases the possibility of injury, and decreases the athlete's ultimate speed potential.

The four regions that need to be attended to by the sprint athlete are:

1. Hip-flexors (psoas major, iliacus, pectineus, tensor fascia latae, and rectus femoris).
2. Hip-adductors (adductor magnus, longus, brevis, gracilis).
3. Hip-extensors (hamstrings, gluteals).
4. Ankle-flexors (gastrocnemius, soleus).

If the athlete attempts to run fast whilst being tight in any of these regions, injury can result. The most common injury that occurs when attempting to sprint fast is the hamstring strain. This muscle group is a two-joint muscle that crosses the knee and hip-joints, which in so doing has a greater stress placed upon it as both these joints are actively involved in the sprinting process. Also, this muscle group is essential in slowing down the lower limb just prior to the ground-contact phase, and the incidence of injury at this point of the running stride is high.

The athlete who has to sprint regularly in their sport requires two types of flexibility: static and dynamic. Static flexibility is measured by the athlete's ability to take their limb passively through a large range of motion. A good example of static flexibility is the gymnast who can do the splits. This type of flexibility ensures that the athlete will not be limiting range of motion due to muscle lengths that are too short for the movement required. If the hamstrings are short, for instance, then when the athlete attempts to stride out, the hamstring muscles will be placed under large stress, which could result in injury. The same issue applies to the adductor and hip-flexor muscle groups during certain parts of the sprint technique.

Dynamic flexibility is the ability to take a limb through the required range of motion in a dynamic (swinging) manner. It is just as important as static flexibility because sprinting requires flexibility to occur during the actual sprint performance. Dynamic
flexibility is particularly useful for warming athletes up prior to a training session or competition. (See Chapter 6 for more information on this topic)

## Coaching Implications

1. Reactive strength is best developed through regular plyometrics training.
2. Athletes gifted with high sprinting speed employ a good combination of maximal strength and explosive strength - these two attributes must be trained and properly coordinated in a training program if quality results are required.
3. Stride length should be improved through increased leg strength rather than having the athlete try to lengthen their stride during sprinting (this can lead to overstriding and a decrease in running speed).
4. A decrease in ground-contact time will help increase cadence (stride rate), therefore increasing maximal running velocity and ultimately the performance of speed.
5. Quality sprint technique is very important in maximising sprint speed and in minimising the braking forces during each ground contact.
6. Well-developed hip-extensors and hip-flexors are linked to high sprinting speed performance.
7. Athletes who perform many submaximal sprint performances are conditioning themselves to sprint submaximally, and will not be able to perform repeated maximal sprints if required.
8. The difference between aerobic and anaerobic endurance training should be completely understood. These two attributes should be trained separately.
9. If an athlete does not have to sprint further than, for example, 40 m in a competition, they should not be expected to sprint further than 40 m in training ("sprint" refers to $100 \%$ running effort). Repetition $100-300 \mathrm{~m}$ sprints are of no use to this type of athlete.
10. Static flexibility should be limited during the warm-up (it decreases the neural activation of muscles) and maximised during the warm-down phase. Conversely, dynamic flexibility should be emphasised during the warm-up.

## Chapter 6:

## PREPARATION FOR A SPEED SESSION



From my observations, many coaches and athletes are unsure as to how to best prepare for a speed training session (or even for a dynamic training session), and when to work on speed in a training session, and how speed training fits into the overall training program. This chapter attempts to address these issues and introduces several training elements that will be covered in more detail later in the book.

## 1. THE WARM-UP

An important part of the preparation for a speed session is how athletes warm themselves up for the ensuing high-intensity work-out. Athletes who do this inadequately will not gain the maximum benefits from such a session, and may
potentially injure themselves in the process. Preparing the nervous system for rapid muscular contractions requires a warm-up which utilises similar motor patterns.

The traditional warm-up, consisting of a general jog followed by several minutes of static stretching, is not the most appropriate way of preparing for a speed or powertraining session. The athlete should not spend too much time performing static stretching because it may cause the athlete's central nervous system to decrease its activation (the role of static stretching is to inhibit neural activation in muscles), thus not preparing this system for the very active work required during the session.

There are a number of options to choose from for a dynamic warm-up prior to a speed session (see Figure 6a).

| Modification of traditional |  | Callisthenics routine | Any modified game |
| :--- | :--- | :--- | :--- |
| warm-up (options) |  |  |  |
| 1. | Warm-up jog (2-4min) | $5-10$ min of active | Touch football etc |
| 2. | Static stretching (30sec) | exercises requiring the |  |
| 3. | Run-through or drill | athlete to run, jump |  |
| 4. | Static stretching (30sec) | and take the limbs |  |
| 5. | Run-through or drill | dynamically through a |  |
| 6. | Repeat until the athlete | large range of motion |  |
| is |  |  |  |

Figure 6a. Examples of dynamic warm-up routines
With the modified warm-up, the addition of static stretching is more for the psychological benefit of the athlete. Most athletes have performed static stretching as part of their warm-up routine for most of their athletic life and to ask them to suddenly stop this type of activity can be mentally tough. The approach detailed above retains the static stretch but it is kept short and is alternated with active warmup techniques such as running or the performance of certain drills that may need to be emphasised in training.

The key to the run-throughs or drills in this warm-up is to be progressive with the intensity so that the last couple of runs or drills are performed at $100 \%$. The total time
for this warm-up is approximately $10-15 \mathrm{~min}$ with the athletes then fully ready to perform a maximal speed session.

I use a modification of gymnastics and callisthenics for certain groups. This type of warm-up can involve running a sort of aerobics session, with combinations of bodyweight exercises (e.g. push-ups, sit-ups, squats), jumping, skipping, running, balls, small hurdles etc. It is possible to add music to the session and teach moves similar to those used when dancing. There is no right or wrong way of warming up a group - as long as they are having a good time and getting warm then it is a functional warm-up routine.

Another successful method of warming athletes up is to play some sort of modified game to prepare them for training, for example touch football. The game can be altered to include more sports-specific components such as kicking, throwing, jumping, running with the ball etc.

## 2. THE WARM-DOWN

At the end of any training session it is important to allow the body to return to its undisturbed, rested state (to warm down, or cool down). Training and competition disturb the body's natural homeostasis and a return to this balance is essential for maximal recovery between sessions. The disturbance during a speed session is significant, especially to the nervous system, so a well-structured warm-down will aid greatly in long-term speed improvements.

Apart from a reduction in central nervous system activation, a warm-down phase will:

- restore energy stores;
- remove waste products produced during the activity; and
- relax the athlete's psychological state.

A typical structure for a warm-down would be an easy jog (2-4min) followed by static stretching ( $5-10 \mathrm{~min}$ ). Static stretching is best performed after training for two reasons:

1. Improvement in range of motion is best achieved when the muscle temperature is at its warmest, which is usually at the end of the training session.
2. Stretching is best performed when the athlete is psychologically relaxed, and this state is easier to achieve after training (when the athlete is tired) rather than prior to a session when the athlete is hyped up for what is to come.

Recovery processes relating to the central nervous system are slow compared to those of other systems. To improve an athlete's movement speed over time, recovery must become an integral part of the training program. The harder the session, the longer the warm-down should be to return the body to a resting state. This type of warm-down will allow the body to recover faster and therefore to be fully ready for the next planned session.

## 3. WHEN TO DO SPEED WORK IN A TRAINING SESSION

Of great importance to the development of speed is the freshness of the athlete prior to the speed session. Speed work should ideally be performed directly following the warm-up. This ensures that the athlete is not fatigued from other components of the session, and is psychologically fully prepared for maximal speed efforts.

There is no case for having speed training at the end of a training session. Speed is only developed when the athlete's nervous system is fresh. Once an athlete has developed the appropriate speed attributes, speed could be performed under fatigued conditions to improve the speed-endurance component of fitness. This would increase the athlete's ability to perform repeated sprints under fatigue, which is a requirement for most sports.

If it is not possible to make the speed session the first training component of the day, it should only occur after a light session performed earlier. From experience, athletes who have performed either weights or endurance training in the morning and then back up to perform speed in the afternoon are usually sluggish and get little from a speed session (they tend to go through the motions, which is not conducive to speed development). This situation can be alleviated somewhat by including recovery sessions between session one and session two (the speed session). This option is only available to those athletes who are able to spend time during the middle of the day performing the recovery techniques (sleep, massage, spa, sauna etc).

More and more frequently, the speed session is taking place after weights and/or plyometrics (jump training). This type of speed work involves distances of up to 2030 m , and could be more appropriately named acceleration training rather than pure speed (maximal running speed) training. To make such a training session successful, it is important that the total volume of work is decreased so that the athlete is not completely fatigued by the time they get to the speed session. It would not be advisable to complete a normal weight session, followed by plyometrics, and then finish off with maximal $20-30 \mathrm{~m}$ sprints.

The structure for such a session could be as follows:

1. Weights ( 30 min working on core exercises - squats, power-cleans, bench-press).
2. Plyometrics ( $10-15 \mathrm{~min}$ of up to 60 jumps - focus on quality not quantity).
3. Sprints (up to 300 m worth of sprinting, e.g. $10 \times 30 \mathrm{~m}$ ).

Performed during the preparation phase of training, this type of training session is conducive to maximising speed and power development. Weights by themselves do not automatically translate to speed and power movements, so with the addition of plyometrics, which is a training tool to develop power (see Chapter 13 for more information on this topic), and short sprints (to develop speed), the athlete can achieve both speed and power gains concurrently with strength gains.

This could be seen as very beneficial in that less time is needed for training, and the traditional conversion phase (strength converted to power, and power to speed) which takes place just prior to the competition phase of the year can be removed from the program, or at least reduced (see Figure 6b). Importantly, the overall volume of training per session must be carefully monitored so that the athlete does not overdo the speed and power work, which will lead to long-term fatigue and the potential for injury.

| General <br> Preparation | Specific <br> Preparation | Pre- <br> Competition | Competition | Transition |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| General Strength |  |  |  |  |  | Hypertrophy | Maximal Strength | Maintenance |
| Plyometrics \& Acceleration Runs |  |  |  |  |  |  |  |  |

Figure 6b. Planning for speed and power training

This program is best used with athletes who have had a couple of years of strengthtraining experience and who are able to physically handle performing low-repetition resistance training for several months at a time. (See Chapter 14 for more information on this topic)

Beginner athletes should be introduced to mixed training routines combining speed, power and strength as it makes training more specific to the needs of the sport (if a speed and power sport). Ensure that the total volume of work is not overdone and that the athlete converts any strength gains from the weight room into the appropriate dynamic speed and power movements.

Medicine ball throws are a very good strength conversion exercise and can give a good indication of how successfully the athlete is using their new found weight room strength. (See Chapter 9 for more information on this topic) It is the coordination of strength in a speed or power movement that is one of the major factors in success in sport today.

## 4. WHEN TO DO SPEED TRAINING IN A MICROCYCLE

For all but the most advanced athletes, the placement of the speed session during the week (the microcycle) is not an issue. For the beginner or social athlete, the training volume will be small and may only amount to two times per week, plus the game or competition (see Figure 6c). In this situation, the best time to develop speed would be on either, or both, of the training days (at the start of the session).

| Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Rest | Training | Rest | Training | Rest | Game/Rest | Game/Rest |

Figure 6c. Example of a typical beginner/social athlete's training week
The coach could include the speed session(s) on either the Tuesday or Thursday, or both. The recovery days between training will ensure the athlete is fresh for all skill and speed components that are to be included in either training session.

If you are dealing with an advanced athlete (training several times per week, plus competition), then the placement of the speed session becomes more important if maximal gains are to be achieved (see Figure 6d). There is little benefit in having the athlete perform a speed session after a day of hard training, or in performing sprints during the second or third session of the day, particularly if the first one or two sessions were highly fatiguing. If possible, the speed session should be the first training component of any day.

| Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Recovery | Weights | Speed | Skills | Recovery | Skills | Game |
| Warm-up <br> \& Run- <br> throughs | Skills | Recovery | Weights |  <br> Speed | Rest | Rest |

Figure 6d. Example of a competition training week for an advanced athlete
Performing a speed session first thing in the morning will be beneficial only if the athlete is given time to allow their body to fully waken from the previous night's sleep. There is little to be gained from athletes performing speed training at 6am if they have only woken at 5.45 am . For the body to have shaken off sleep and to be able to perform high-velocity movements requires that the athlete is awake from anywhere between $2-4 \mathrm{hrs}$ prior to the training session. It has been proven that an athlete should be fully awake to be in the best neural condition for performing speed, strength or power movements. An ideal training time would be $9-10 \mathrm{am}$, which would give the athlete time to fully wake up.

The best placement of a speed session during the week is after a day of low-intensity training. A low-intensity training day may consist of a skill session, flexibility session, medium endurance session, or a medium to low-intensity weight-training session. Speed sessions on consecutive days are not advisable as there is residual fatigue from any session which may affect the quality of the following session, so you therefore start to train the system to perform at a level below that which is optimal for long-term gains.

## Coaching Implications

1. Warm the body up to a similar degree to what is required in the training session. If the session is to be dynamic, then the warm-up should also be dynamic.
2. Modified games are a great way of adding a fun component to any warm-up routine.
3. The homeostatic disturbance following a speed session is significant, especially in the nervous system, so a well-structured warm-down will aid greatly in recovery from these sessions and therefore in long-term speed improvements.
4. Flexibility is best developed when the body is very warm, which is usually at the end of training. This is the best time physically and psychologically to improve static flexibility.
5. Speed work should only be performed when the athlete is in a fresh state. The beginning of any training session is the best time.
6. Speed training at the end of a training session does not help to develop speed but actually improves speed endurance. These two attributes are very different. Training speed does not automatically improve speed endurance and vice versa.
7. When combining strength, power and speed work in a session, it's most important that there is a decrease in the total volume of each element so that the athlete is not overtrained, which could result in injury or long-term fatigue.
8. Speed, like all other physical attributes, is best developed through regular (2-3) sessions per week.
9. During any training week, speed work should be performed on a day that is preceded by a lighter day of training.
10. There is little benefit in performing speed sessions early in the morning, when an athlete has just woken up. Such sessions should be done when the athlete's body has fully awakened, 2-4hrs after they arise.

## Chapter 7:

## TARGETING SPEED COMPONENTS

This chapter examines methods for improving each of the components outlined in Chapter 2 (The Components of Speed). It's my hope that this information will stimulate your thoughts and help you to come up with exercises specific to your own sport or discipline, exercises that will help improve each of the following physical abilities.

## 1. REACTION TIME

As detailed in Chapter 2 (The Components of Speed), reaction time can be explained as the response to an external stimulus, or the interval of time between the onset of a signal (stimulus) and the initiation of a response. This definition does not include the movement itself. The faster the response, the less the individual's reaction time. Reaction time is an important speed attribute for athlete's in a wide variety of sports.

In regard to reaction time, we have already discussed types of stimuli, the benefits of practice, an athlete's readiness for response and their kinaesthetic sense, and choice reaction time. The following sections focus on the latter two topics in terms of drills that can be utilised to develop these aspects of reaction time.

## IMPROVING KINAESTHETIC SENSE OF REACTION TIME

An athlete's kinaesthetic sense is their feeling (through muscles, tendons and joints) of their own reaction time. Following are details of several training drills that can be used to develop this sense in an athlete.

## Training Drills

1. Have the athlete react to a stimulus and move over a measurable short distance (e.g. $2-5 \mathrm{~m})$. At the end of each trial, the coach tells the athlete the time taken, which is indicative of the athlete's reaction time due to the short distance covered.
2. Same as drill number one, but this time at the end of each trial the athlete must determine what their time was prior to the coach stating the correct value. This requires the athlete to start thinking about his or her own performance.
3. In this drill, the athlete is instructed to perform certain trials within a set time, determined by the coach. This forces the athlete to learn to manipulate their own concentration and reaction to a stimulus that has been deemed to be beneficial to the improvement of their reaction time.
4. Have athletes work in pairs. One of the athletes keeps their eyes closed while their partner touches them at some point on their body. When this happens, the athlete with their eyes closed must react by quickly moving towards or away from the direction of the stimulus.

## IMPROVING VISUAL CHOICE REACTION TIME

As explained earlier in this book, there are four major factors that determine the success of the response to the stimulus, namely perception of the stimulus, appreciation of its speed and direction, the decision on what response is appropriate, and carrying out the response. Following are some drills that will develop these abilities in athletes.

## Training Drills

1. The athletes have their eyes closed. On a command, they must open their eyes and respond to an instruction given by the coach, e.g. quickly spot a cone and sprint to where it has been placed.
2. The athlete has to respond in an appropriate way to a choice between two differentcoloured flags, e.g. the red flag means X, and the blue flag means Y. This encourages the athlete to improve their mental processing of the visual stimulus presented to them.
3. The athlete sprints from point A to point B and during the run is instructed to run either left or right via a simple command from the coach (e.g. lifting the left or right arm).

The above drills can be modified to incorporate both auditory and kinaesthetic receptors, such as using different sounds, or having athletes react to being touched.

For example, have a number of athletes stand in a line one behind the other. Athlete number one touches athlete number two on the shoulders, which is the cue to have athlete number two touch athlete number three on the shoulders etc. This can be done in two or three groups as a competition and is an engaging way of improving an athlete's response to a variety of stimuli.

To maximise reaction time it is also important to have an athlete concentrate on their response to the stimulus and not the stimulus as such. For example, the athlete who has to respond to a starting pistol will have a better reaction time to the stimulus if they concentrate on their initial movement and not on the sound of the gun. It's a similar situation with visual cues - have the athlete concentrate on their initial response to the stimulus and not on the actual sighting of the object.

## 2. AGILITY

Agility is a combination of speed, strength, power, balance and coordination. This attribute is best trained by having an athlete repeat agility movements that are specific to the demands of their sport. Developing general agility is fine but it is only when the effort is directed at specific movement patterns that an athlete can become highly proficient at the specific demands of their particular sport.

## AGILITY \& COORDINATION SESSION

The following types of drills are extremely useful if the main emphasis of training is on improving agility and coordination.

## Training Drills



1. Young athletes are required to move quickly in several directions (forwards, backwards, sideways) on both audio and visual commands.
2. The athlete must take a quick step over, around etc a series of markers on the ground (hurdles, lines, balls, cones).
3. The athlete performs heel flicks, heel clicks, ballet drills, skipping 'A's, 'B's and 'C's, hurdle abductor drills, stiff-ankle drills, line-coordination drills; these are performed forwards, backwards, with eyes closed, over two lines forwards, fast feet in and out of line.
4. Two athletes face each other and as one moves, the other mirrors these movements. Repeat these "mirror drills" for a specific amount of time or number of moves.

## (See Chapter 12 for more information on this topic)

## HAND-EYE COORDINATION SESSION

The development of hand-eye coordination proceeds rapidly from the age of two through to an athlete's teenage years. By six years of age, an athlete should have mastered most of the fundamental skills, which are then refined to become specific to the demands placed upon them (e.g. through music, sport, dance etc). One important aspect of the development of agility and hand-eye coordination is the initial sighting of the object. Visual acuity is well developed at the teenage to adult level but is still developing in the young child. In a training situation involving a child, the object must be large enough and must contrast adequately enough with the background to ensure the child can see it before attempting some hand-eye coordination movement.

From teenager to adult, the improvement of hand-eye coordination also results from the subject's ability to be able to quickly perceive the placement of the object, its speed, and its direction of travel. These motor skills can be improved by ensuring there is sufficient variation in stimuli during the formative stages of training. For examples, see the following training drills.

## Training Drills

1. Throw balls at an athlete from different directions and at different velocities and times.
2. The athlete must bounce two balls. Have the athlete bounce both in synchronisation, then out of synchronisation (e.g. only one hits the ground at any one time). Ask the athlete to bounce the balls whilst hopping on one leg, jumping on both legs, skipping, walking or jogging backwards or sideways, through a series of cones etc.
3. The athlete bounces a single ball whilst walking, skipping or jogging, either forwards, backwards or sideways. This drill is identical to the one above except that the athlete uses only one hand to bounce the tennis ball, netball etc. Have the athlete change hands regularly.
4. The athlete is required to block balls that are thrown at or past them.
5. Again using two balls, the athlete must bounce one and roll the other on the ground.
6. The athlete juggles two or more balls.
7. A pair of athletes bat two balls back and forth between them - the balls should not be caught.
8. Two athletes play a modified form of basketball involving two balls, where the goal is to knock the ball being bounced by your opponent away from them whilst maintaining control of the ball you are bouncing.
9. An athlete is required to throw two balls in the air and must try and catch one in each hand. Begin with tennis balls and then move on to larger balls (e.g. a netball).
10. A variation of the above drill is where the athlete must catch the ball thrown with one hand in the other hand.
11. Another variation of the above involves the athlete completing a $180^{\circ}$ or $360^{\circ}$ turn or jump before catching the ball/s.

## PERIPHERAL VISION

The development of an athlete's peripheral vision is vital in ensuring good agility and hand-eye coordination. Peripheral vision is the ability to detect an object or movement away from the direct line of sight. In team sports this attribute is important as it allows a player to have a better grasp of their total surroundings and may allow them to "read a game" more efficiently. As with hand-eye coordination, peripheral vision can be best developed by supplying a subject with varying stimuli from a range
of different directions (also at different speeds, and in different sizes and colours) and asking the subject to catch, hit or avoid the moving object. The development of this skill is best done during the neural-forming years of $6-12$, but should also be continuously addressed throughout an athlete's playing years.

## Training Drills

1. Objects are thrown at the athlete from different directions, e.g. from out of the athlete's line of sight and into their line of sight (from side on, behind etc).
2. Have athletes compete against each other in trying to touch each other's feet, knees etc without looking down.
3. Have the athlete either catch or evade objects thrown at them from more than one direction.
4. A fun session for younger children is to get them to each keep a balloon in the air as they get better at this activity, add more balloons. To keep more than 2-3 balloons in the air at any one time requires good vision and agility on the part of the athlete.

## 3. ACCELERATION

It should now be clear that acceleration is highly dependent upon strength, in particular strength relative to one's own bodyweight (this is known as relative strength). Resisted and assisted training techniques are ideal for developing this attribute, as are accelerations and explosive strength training.

## RESISTED TRAINING

If an athlete's body is overloaded through the use of a resisted training technique, the adaptation that takes place will help that athlete more quickly overcome their bodyweight and consequently accelerate faster. (See Chapter 10 for more information on this topic)

## Weighted-Vest Running

In this activity, the athlete performs varied sprints whilst wearing a weighted vest. The weight should be such that there is only a $5-8 \%$ increase in bodyweight. A
weighted vest could also be worn whilst performing bounding activities (plyometrics).

A combination of running with and without the vest (contrast training) is also beneficial to improving acceleration. The body recruits a greater number of muscle fibres during the weighted-vest run which can then be transferred to the non-weighted run environment, resulting in greater force output and therefore a faster acceleration phase.

## Weighted-Pants Running

Weighted pants, initially designed in the USA, can be worn by an athlete when they undertake drills, running, bounding and hill sprints. The main benefit of using this training device is that specific sprint muscles (hip-flexors, extensors, abductors, adductors) can be trained without the athlete having to place potentially excessive stress on their lower back though the use of a weighted vest.

## Towing \& Uphill Running

Both towing and uphill running increase the force output needed to overcome the body's inertia, thereby increasing the demand on the relevant muscles in the legs and upper body. To emphasise the acceleration phase of running, these drills should be performed at a high intensity and with varying weights (towing) and inclines (hill sprints).


## ACCELERATIONS

The most movement-specific training modality that can be used for acceleration improvement is speed training itself. By performing repeated acceleration runs (from $10-60 \mathrm{~m}$ ) under a variety of different conditions - uphill, downhill, towing a sled, being towed along by a speed-enhancement device - an athlete can achieve substantial improvements in their acceleration ability. This type of training helps to increase an athlete's immediate energy stores (adenosine triphosphatephosphocreatine) which will allow them to produce energy faster and have more energy to perform the required activities.

## Training Drills

Have the athlete perform repeat sprints over $10-60 \mathrm{~m}$ with walk-back recovery, e.g.:

- $5 \times 10-30 \mathrm{~m}$, walk back ( 3 min rest) and repeat 2-3 times;
- $3 \times 40-60 \mathrm{~m}$, walk back ( 3 min rest) and repeat 2-3 times; or
- other similar combinations, which could include swerving, lateral movements, backwards movements etc.

These exercises can be modified so that the athlete starts from a variety of positions (on their back, side, face-down etc), with the key being the performance of these runs at $100 \%$ intensity. For sports where the ability to change direction is important, the accelerations can be further modified so that the athlete has to run around a series of cones, tackle bags, or respond to a ball thrown into their line of running.

## ASSISTED TRAINING

Assisted training techniques can also benefit the development of acceleration ability. A decrease in an athlete's inertia (bodyweight) is achieved through the use of a device which helps pull the athlete over a set distance. This can assist in having the athlete 'feel' what it is like to move fast and help retrieve the motor patterns required for greater movement speeds. (See Chapter 11 for more information on this topic)

## EXPLOSIVE STRENGTH TRAINING

Plyometrics, or bounding, is an intense but extremely effective method of improving an athlete's performance during the acceleration phase. The correct implementation and periodisation of this training modality will lead to great improvements in performance. (See Chapter 13 for more information on this topic)

## 4. MAXIMAL RUNNING VELOCITY

There are three things that need to be targeted during training to develop maximal running velocity:

1. Technique enhancement - this is crucial to the correct development of motor patterns for optimal speed gains.
2. Maximal strength - this is needed to offset the eccentric forces developed during the ground-contact phase of each stride (the less drop in the centre of gravity with each stride, the easier it is to maintain the correct body position at high speed).
3. Reactive strength - this relates to the athlete's ability to use the stretch-shortening cycle, and ensures they spend minimal time on the ground with each ground contact and maximise stride length through a forceful push-off to the next stride.

A training regime which aims to improve the maximal running speed of an athlete should therefore lead to the development of high strength levels in leg musculature and the mid-torso (see Chapter 8 for more information on this topic), and also to the development of reactive strength (through repeated plyometrics). Another important outcome is the development of a faultless technique, which can be achieved through repeated submaximal and maximal sprint efforts. The guidelines for an efficient sprinting technique are a slightly forward body lean, efficient front-side mechanics, minimal ground-contact time, and strong and powerful hip-extensors (gluteals and hamstrings). (See Chapter 3 for more information on this topic)

## Training Drills

Speed runs should be performed to improve an athlete's maximal running velocity, specifically:

- flying 30-40m sprints; and
- $120-150 \mathrm{~m}$ sprints (specific to track athletes).

Flying $30-40 \mathrm{~m}$ sprints require the athlete to have a $20-30 \mathrm{~m}$ acceleration phase followed by $30-40 \mathrm{~m}$ during which the athlete is attempting to run as quickly as possible. It is important that the acceleration phase is performed smoothly, allowing the athlete time to focus on correct technique as they approach the start zone. Accelerating too hard too early will have a negative effect upon technique, and will lead to technical faults during the $30-40 \mathrm{~m}$ maximal speed phase.

For any speed development session I would look at having the athlete perform 5-10 30 m sprints with $3-5 \mathrm{~min}$ recovery between each run. This ensures that the athlete fully recovers and is able to put in a maximal effort during the next repetition.

Sprints of $120-150 \mathrm{~m}$ should be performed in such a way that the athlete accelerates smoothly over the first $20-30 \mathrm{~m}$ and then maintains a high cadence over the remaining distance. Checkpoints can be positioned along the way to flag a change in velocity or an increase in cadence whilst the athlete is sprinting. The reason behind the set range of $120-150 \mathrm{~m}$ is that it allows the athlete to focus on the technical elements that are required without having to rush to get into the correct running position.

If $120-150 \mathrm{~m}$ runs are to be included in a sprint program, I would only expect the athlete to perform 3-5 of these runs with 5-8min between each run. As with the flying sprints, this is to ensure that the athlete has recovered from the previous run and is able to give a maximal effort during the next repetition.

Another training modality which will help improve maximal running velocity is overspeed, or supramaximal, speed training. This utilises a training device such as a Speed Belt or Ultra Speed Pacer and works on the principle that regular sprinting above the speed an athlete is able to generate without aid helps improve the relevant motor patterns, thereby promoting improvements in unassisted sprint performance.

## (See Chapter 11 for more information on this topic)

## 5. DECELERATION PHASE

The deceleration phase occurs either at the end of a single sprint performance (any distance over $60-70 \mathrm{~m}$ will have a deceleration phase) or after repeated short sprints (as in a team-sport or court-sport situation). The maximisation of speed as the athlete
fatigues is dependent upon a well-developed anaerobic energy system. This will ensure continued supply of the energy requirements during the high-intensity activity.

The development of speed endurance is quite different to the development of general aerobic endurance. An aerobically fit athlete does not, as an automatic result, have a anaerobic system which is more resistant to fatigue. To best train the anaerobic system, the athlete needs to repeat intense sprints until fatigue sets in. The athlete is then given time to recover and the process is repeated. It is this continual placing of athletes under anaerobic fatigue that leads to the adaptation that is expressed as speed endurance.

## Training Drills

1. The athlete performs intense $(90 \%+$ ) runs over distances of $100-500 \mathrm{~m}$ (quite specific to track sprint athletes).
2. The athlete performs a series of repeated short sprints ( $20-60 \mathrm{~m}$ ) with set recoveries (specific to all team-sport and court-sport athletes).

I believe there is little benefit in asking team-sport or court-sport athletes to run distances greater than $30-60 \mathrm{~m}$ at speed. Running such distances at tempo speed (60$75 \%$ ) is more than appropriate for quality aerobic development, but has no place in the development of speed endurance.

Team and court sports demand continual stopping and starting, and this can be trained specifically through repeat intervals of short distances. It is much tougher to have to run $3 x 50 \mathrm{~m}$ back to back at $100 \%$ then to run 1 x 150 m . The deceleration and reacceleration of the athlete's bodyweight is much harder on the anaerobic system than the maintenance of speed over 150m. (See Chapter 17 for more information on this topic)

## Coaching Implications

1. Variety in the types of stimuli and response is a key factor in maximising the development of reaction time.
2. The athlete should practice developing new movement possibilities (e.g. additional kinds of tennis shots) to increase the number of possible stimulus alternatives to present to an opponent.
3. Hand-eye coordination is best developed by employing objects of varying size and colour during training, also by varying the speed and direction of objects which are thrown.
4. Resisted training to improve acceleration can be in the form of resisted sprints, bounds, hill runs or jumps, and specific strength-training routines.
5. For resisted training, weighted pants are preferable to a weighted vest as the load increase is not focused on the athlete's mid-torso or lower back.
6. Repeated acceleration runs ( $10-60 \mathrm{~m}$ ) will help develop an athlete's ATP-PC system.
7. The achievement of a high maximal running velocity relies on training which emphasises correct technique, and the development of high levels of maximal and reactive strength.
8. Maximal running velocity should only be developed in athletes who have to regularly run over 40 m .
9. The athlete who is stronger and in better anaerobic condition will suffer less of a decrement in their deceleration phase in either a single sprint or after repeated sprints (such as in a game).
10. Short, repeated intervals are preferred over long $100 \mathrm{~m}+$ distances when developing speed endurance, as these more closely simulate team and court-sport movement requirements.

## Chapter 8:

## THE MID-TORSO \& SPEED PERFORMANCE

Most sports involve relatively extensive movements of the trunk. Since the trunk segment has a large mass, great demands are exerted on the trunk musculature, particularly if the trunk movements are to be performed with high accelerations. The trunk also has a critical role in the maintenance of stability and balance when performing movements with the extremities.

This chapter aims to highlight the different segments of the mid-torso and their collective role in speed performance, and to present the appropriate exercises for training this region in both a general and a speed-specific manner.

## 1. ANATOMY \& KINESIOLOGY

The mid-torso region is composed of four major muscle groups: rectus abdominis, external oblique, internal oblique, and transverse abdominis. These muscles work in a synergistic manner to give support to the pelvis in either minimising unwanted movements (e.g. rotations during sprinting) or to create movement (e.g. bending to reach for a ball).

## Rectus Abdominis



Outer - pubic crest and symphysis
Inner - xiphoid process and costal cartilage ribs 5-7

Role in body movement:

- vertebral flexion;
- lateral flexion;
- pelvic stabilisation during walking and running; and
- increased intra-abdominal pressure.


## External Oblique



Obliques

Outer - outer surfaces of lower eight ribs
Inner - most fibres insert anteriorly via a broad aponeurosis along linea alba; some fibres attach to pubic crest

Role in body movement:

- vertebral flexion;
- lateral flexion;
- opposite-side rotation;
- increased intra-abdominal pressure; and
- lumbosacral stabilisation.


## Internal Oblique

Outer - iliac crest and inguinal ligament
Inner - linea alba, pubic crest and last three ribs

Role in body movement:

- vertebral flexion;
- lateral flexion;
- same-side rotation;
- increased intra-abdominal pressure; and
- lumbosacral stabilisation.


## Transverse Abdominis



Transversus Abdominus
Outer - iliac crest, inguinal ligament and cartilage of last six ribs
Inner - linea alba, pubic crest

Role in body movement:

- compresses abdominal contents; and
- increases intra-abdominal pressure.


## 2. FUNCTION OF THE MID-TORSO IN SPORTS ACTIVITIES

Sports activities requiring running or jumping place pressure on the lumbopelvic region (which includes the $4^{\text {th }}$ and $5^{\text {th }}$ lumbar vertebra), the pelvis and the hips, as this region becomes the hub of weight-bearing. It is here that the superior forces (from torso, head and arms) meet the inferior forces transmitted from the ground through the lower extremities. No part of the body is more vulnerable to tissue strains and sprains. This point is the centre of all body movement - efficient body movements (as required in sprinting) can only be achieved by this area being very stable. There are three broad muscle collectives that are important in maintaining the stability of an
anatomically correct body position: the abdominal muscle groups, erector spinae (comprising the mid-torso muscle groups), and the gluteus maximus.

Research has been done on the mid-torso muscle groups to see which group had the greatest impact on lumbopelvic stabilisation. Results indicated that the oblique and transverse abdominis muscle groups are the most important for this stabilisation (especially from pelvic rotation forces) as found in high-speed sprint movements.

A powerful arm drive, assisting in sprint acceleration, will allow for a more rapid and powerful leg extension. The limitation with this technique is that large rotational forces can be placed upon the mid-torso musculature. If there is inadequate stability in this region, excessive rotation of the pelvis will occur to counteract shoulder rotation, resulting in poor technique and inefficient force application - a slower athlete will be the result. At an elite level, upper-body strength is emphasised in sprint athletes but with a concurrent development of mid-torso strength to allow efficient usage of this additional strength during high-speed sprinting movements.

The naturally occurring wide pelvis of the mature female also leads to the above pelvic rotation problem - mid-torso strength is absolutely vital if a coach wishes to maximise efficient technique at maximal speed in his or her female sprint athletes. Hip rotation is required to maximise stride length but if this is excessive then poor technique will result, and if combined with a poor pelvic tilt (anterior tilt) then major inefficiencies will result leading to either poor performance, injuries, or both.

Apart from resistance to rotational forces, there must also be support for the pelvis to minimise excessive anterior pelvic tilt. An excessive anterior tilt indicates poorly toned mid-torso musculature and this can increase the lordotic curve (lower back arch) in the lumbar region. This will increase the strain on the facet joints in the vertebral column and can result in the iliopsoas going into spasm to protect the lower core from injury. Also, increased pressure on the neural plexus from the lumbar region can result in nerve irritation (e.g. of the sciatic nerve) which can then affect the optimal functioning of lower limb musculature, with consequent deleterious effects (hamstring strains) if work involving maximal effort (e.g. 100\%-intensive sprinting) is performed.

Excessive anterior tilt of the pelvis can limit hip range of motion, leading to excessive hip-extension and limited hip-flexion. This technical position limits stride length and increases ground-contact time (which is undesirable when increases in speed performance are being sought) due to the athlete's centre of gravity being lower than required for correct accelerative or maximal sprinting speed.

The demands of sprinting require the abdominals to function in a way that leads to optimal torsional stabilisation during explosive contractile sequences, matching the needs of performing up to 5 strides per second (such as that which occurs in an elite sprint race). During sprinting at this rate, the lower limb velocity can reach $80 \mathrm{~km} / \mathrm{h}$. Therefore, the stresses placed upon the pelvic stabilisers are extreme and can only be accommodated by extremely well-developed abdominal (including oblique) musculature.

## 3. DEVELOPING THE MID-TORSO

The development of a strong mid-torso should be a goal for all speed and power athletes. The question most often asked in relation to this is what is the best way to develop abdominal strength (this should include all mid-torso muscles) which can then be converted to the functional strength required in everyday sports movements.

The preferred procedure for maximising abdominal strength is the common sit-up. From a kinesiological perspective, the sit-up and its many variations are the ideal exercises through which to develop the vertebral flexor and rotational muscles (namely the rectus abdominis, external oblique, internal oblique, and transverse abdominis).

The mid-torso musculature consists of postural muscles with a high percentage of slow-twitch muscle fibres. Their function is to hold contractions for long periods to maximise trunk stability. To best condition this region, variations on the sit-up can be used. To maximise abdominal development and minimise the stress placed upon the lower back, exercises should be performed slowly ( $1-4 \mathrm{sec}$ per repetition) whilst working on all muscle groups in the mid-torso region. These exercises should also be
performed through a range of motion that minimises lower back strain, and where maximal control is emphasised.

When compared to the stress placed upon the lumbar region when standing (assume this is measured as $100 \%$ ), the full sit-up, even with knees bent and feet on the floor, creates a lumbosacral stress equal to $200 \%$. This load can be decreased if the sit-up is only partial (first $30^{\circ}$ from floor) and will be lessened even more if a reverse sit-up is performed (the pelvis is lifted off the floor). The reverse curl has been shown to increase the activation of the external oblique and internal oblique, as well as the rectus abdominis. A modification that will maximise the load and minimise the stress upon the lumbar region is to perform a partial crunch and a reverse sit-up concurrently, and to hold each maximal contraction for $2-4 \mathrm{sec}$. This minimises the use of assistant muscle groups and quickly fatigues the musculature targeted in only 5-15 repetitions.

Sit-ups performed fast and/or with the feet supported have:

- the relative contribution of the hip-flexors increasing whilst the relative contribution of the abdominal muscles are decreasing;
- increased stress placed upon the lumbar region of the spine; and
- decreased load on the abdominal musculature due to increased momentum from the upper body.

The major limitation of the sit-up is the functional application of mid-torso strength transferable from a sit-up routine to the pelvic stabilisation required under the stresses of a sprint or any high-speed movement performance. The observation of athletes in many different sports has revealed that even the development of a very strong midtorso region from sit-ups does not automatically translate to the pelvic and mid-torso positions required to maximise sprinting performance. Many athletes are strong enough through their mid-torso region but have not developed the correct motor patterns to be able to stabilise the body whilst performing rapid upper and lower limb movements (e.g. arm and leg movements in sprinting). Development of the specific strength qualities or transferral of mid-torso strength to the required strength positions can be achieved both in a weight room and on-site (on a field, court or track).

## 4. WEIGHT ROOM MID-TORSO TRAINING

Whilst it doesn't necessarily have to, most abdominal training takes place in the weight-training environment. This training should be a combination of general and specific strength exercises, using concentric, eccentric and isometric contraction training from non-specific to sprint-specific body positions to best develop the midtorso. Once the athlete can perform acceptable generic mid-torso exercises, more sprint-specific positioning can be introduced which requires the athlete to place their hips in the necessary posterior tilt position whilst placing stress upon the mid-torso musculature.

## Training Drills

The following are examples of basic isotonic/isometric exercises:

1. Abdominal hollowing - build up to 60 sec holds.

2. Isometric prone and all variations.


3. Single-leg raise with lumbar support and variations - up to 15-20 repetitions.

The above are passive isometric exercises that, once a high level of competency is achieved, can be followed by active isometric exercises which are highly sprintspecific. Examples of active isometric exercises are:

1. Rapid hip-extension/hip-flexion - build up to 30-40 repetitions.

2. Modified Russian twist with/without arm swing - build up to 30-40 repetitions.


3. Alternating clap sit-ups - build up to 40-60 repetitions.

## 5. ON-SITE MID-TORSO TRAINING

Strength training is purely a precursor to what must be achieved "on the field", or onsite. This is where the application of strength gains can be properly assessed and where true transfer can be completed.

## Training Drills

1. The correct body positioning can be enforced through several running drills which are aimed at correct running form (which usually means correct body posture through the mid-torso). The 'A', modified single-leg 'A', 'B', heel-flick, high-knee drills, and various modifications of these drills are all aimed at increasing the tilting and rotational stresses that are placed upon the mid-torso musculature. These drills can be done slowly at first and progressively sped up as the athlete's ability to hold the correct position improves.
2. Have the athlete sprint whilst concentrating on the body positioning drilled previously. Sprints should be less than maximal at first, progressing only as the athlete is able to maintain the correct running position. As soon as pelvic stability decreases, the drill should be stopped. During training, the focus on the mid-torso can be increased if you have the athletes perform several abdominal exercises prior to performing an acceleration run. The increased tension in the abdominal region due to the specific work performed allows the athlete to more easily focus on the region whilst performing a submaximal sprint run. Care must be taken with this type of exercise so that you don't fatigue the athlete in this region to the extent that they are too tired to hold the positions that are needed during the sprint performance. As the
athlete increases mid-torso conditioning, the performance of 20-30 sit-ups prior to a run will further increase mid-torso stability rather than decreasing it.
3. External resistance can be applied in the form of a towing device that an athlete places around their mid-torso. The pressure on this region through each repetition reinforces the control required as the athlete is having to work harder to maintain good body position under this increased resistance. (See Chapter 10 for more information on this topic)

## 6. VARIATIONS OF MID-TORSO TRAINING

A traditional problem with mid-torso training is that the same old exercises are used over and over again, leading to boredom and stagnation in results. The aim of the next section is to introduce you to many different mid-torso exercises, which can be used as a reference when you wish to modify a program and add some new exercises to keep up an athlete's interest.

## SIT-UP LIST

I have supplied a number of variations on the traditional sit-up to ensure there is adequate variety in the abdominal training program.

## IAN COLLIER ABDOMINAL STABILISER PROGRAM

Ian Collier (an ex-Australian rugby union physiotherapist who unfortunately passed away in 1997) designed this program to help develop functional pelvic stabilisation through a series of controlled abdominal exercises performed in either a supine or standing position. As the athlete improves their strength in this region, measured via an abdominal biofeedback machine, there are more advanced programs for them to strive for.

## BIOFEEDBACK TRAINING PROGRAM

The biofeedback device referred to here can be used as a training tool and not just as a testing device. The athlete can monitor readings on this machine whilst performing a
variety of exercises on a daily basis. This can quickly teach an athlete the correct muscular patterns required to maximise mid-torso stabilisation.

SWISS BALL EXERCISES



The latest device to gain good training reviews is the Swiss ball. This device was designed in Europe many years ago in an attempt to help improve the condition of patients with a variety of neuromuscular disorders. The balls have now been implemented in athlete training programs and have proven to be highly useful in the mid-torso education of athletes.

These balls can be used in three particular contexts:

- neuromuscular coordination of the entire mid-torso region;
- advanced mid-torso strength training exercises; and
- sports-specific activities using medicine balls, weights etc.

See Reference section for Swiss Ball resources.

## PILATES

Pilates involves the neuromuscular re-training of transverse and oblique musculature through slow, controlled, specific movements.



See Reference section for Pilates resources.

## Coaching Implications

1. The mid-torso is the hub of weight-bearing and as such needs to be strong to minimise the impact of running and jumping - it must also be able to produce or control powerful rotation movements as required in all facets of sports performance.
2. The "six-pack" that so many athletes are after is much more aesthetic than practical. Well-developed transverse abdominis and oblique abdominis muscles groups are what will lead to the best trunk stability and force application during sport and exercise.
3. A poorly developed mid-torso increases the stress placed upon the lumbar vertebra, leading to tightness of lower limb musculature and possible injury (the nerves that feed the lower limbs stem from the lumbar vertebra).
4. Pelvic rotation problems can be encountered by mature female athletes due to the width of the pelvis - the development of mid-torso strength in these athletes is important in overcoming any potential difficulties.
5. The common sit-up is an ideal exercise for developing each of the four main muscle groups of the mid-torso region.
6. As the mid-torso musculature is composed mainly of slow-twitch fibres, there should be a combination of fast and slow abdominal movements to ensure all areas and fibres of this region are adequately trained.
7. In the early stages of development of adequate pelvic stability, volume is important (building up to several hundred abdominal repetitions each session), but once a solid strength base is developed then intensity should become a greater focus (decrease the repetitions and increase the difficulty of the exercises that the athlete attempts).
8. Mid-torso conditioning should take place in both the weight room and on-site (or sports-specific) environments - on-site training is where the true transfer of strength gains can take place.
9. The development of pelvic stability is a slow process, one that needs to be focused upon continuously throughout each training year.
10. Every athlete should combine mid-torso strengthening exercises (sit-ups and variations) with pelvic stability exercises (Swiss ball, medicine ball, Pilates etc).

Chapter 9:
MEDICINE BALLS \& SPEED DEVELOPMENT




The greatest struggle the speed and power coach faces is the transfer of their athletes' strength to the specifics of the sport. There is much evidence of athletes making great gains in strength in the weight room environment, but relative percentage improvements out in the field fall far below expectations. Many new training modalities have been used to aid in strength conversion, among them towing and plyometrics (see Chapters 10, 11 \& 13 for more information on these topics). A training modality that was in vogue in Australia 15-20 years ago, but which has since fallen out of favour, is the use of medicine balls to transfer strength gains to speed and power movements.

## 1. MEDICINE BALL OVERVIEW

Medicine balls come in a range of sizes, materials and weights, ranging from $0.5-10 \mathrm{~kg}$ or more. The traditional medicine ball is made from vinyl or leather, enclosing a combination of sawdust, sand and padding material. New technology has led to the development of the rubberised medicine ball. Some advantages of the rubber ball over the leather ball are that it is waterproof, and it bounces and doesn't lose its shape. It does not tear open, it's easy to grip even when wet, and it rolls quite well if needed for that type of activity. It also comes in a range of sizes (each size is in a different colour).

Medicine balls have an advantage over other types of weighted implements in that they are easy to throw and catch. They are soft and will do less damage than a metal shot or dumbbell if accidentally dropped by (or for that matter, on) an athlete. They can also be used in a variety of training situations, both inside and outside the weight room environment.

Speed athletes can use medicine balls for:

- specific mid-torso exercises;
- general and specific body conditioning exercises;
- balance and coordination exercises; and
- sprint-specific activities.


## 2. SPECIFIC MID-TORSO EXERCISES

With the use of medicine balls (or medballs), the coach can increase the number of exercises performed and the number of repetitions per session in a way that makes a session more enjoyable for an athlete. In Chapter 8 (The Mid-Torso \& Speed Performance) I argued that it is not ideal to have athletes performing abdominal exercises that are non-specific to the activity at hand. Mid-torso strength conversion can be achieved through a series of individual and paired exercises using a variety of weighted medballs.

The oblique musculature is vital to quality trunk stability. The following exercises aim to develop this region in a functional manner along with the rectus abdominis and transverse abdominis muscle groups.

## Training Drills

1. Standing twisting passes.
2. Overhead passes.
3. Rotational passes.
4. Seated twisting passes.
5. Supine ball raise with legs.

6 . V-sit with ball.
7. Sit-ups with ball catches, legs grounded.
8. Sit-ups with ball catches, legs off ground.
9. Isometric abdominals with ball catches.
10. Knee-raise with ball between knees.
11. Seated twisting medball abdominals.

The correct development of the mid-torso and the hip-flexors is vital for maximal speed training, and many of the above exercises develop both regions in a speedspecific manner. The hip-flexors should be able to contract maximally while the midtorso controls such a contraction, minimising inefficient movement through the hip region.

## 3. GENERAL \& SPECIFIC BODY CONDITIONING EXERCISES

I use the following exercises as part of a dynamic warm-up (see Chapter 6 for more information on this topic) and also between training sets either in the weight room or out on the field, track, court etc.

## Training Drills

1. Big circles.
2. Head circles/touches in prone position.
3. Prone medball raises (overhead).
4. Prone medball raises (side).
5. Overhead figure of eight.
6. Medball lunges/side-lunges.
7. Hip-flexor raises.
8. Hip-extensor raises.
9. Medball kicks.

All of the above exercises are designed to strengthen specific body parts or develop general body strength and condition. The range of weights used can vary from $1-8 \mathrm{~kg}$ depending on the exercise and the strength level of the athlete.

I have found these exercises to be particularly beneficial in situations where the athlete or their parents or guardians do not believe traditional weight-training is appropriate. It has been quite easy to convince them that this is a great alternative to weight-training. Whilst in the long term, strength gains from medball use will plateau, in the short term the athlete can continue to do this strength work without even realising they are actually doing strength training. This example can be extended to the situation where as a coach you are dealing with pre-adolescent children. These
children can be performing a wide variety of strength activities for many years using medballs before they ever need to be introduced into a weight room environment. The introduction of medball exercises to 8-10 year-old children would overcome many of the basic conditioning problems faced when dealing with these children five or so years down the sporting track.

## 4. BALANCE \& COORDINATION EXERCISES

Another use of medballs is to improve the balance and coordination of your athletes. As part of a warm-up routine or a specific conditioning component of a session, it can be beneficial to have your athletes throw medballs to each other whilst forcing them to maintain balance.

## Training Drills

1. Throw a ball at the athlete from a number of different directions, whilst not allowing the athlete to move their feet, or the athlete has to stand on one foot, or they must catch the ball whilst in a squat position, lunge position etc.
2. Have a number of athletes pass a ball in a rotational manner whilst varying body position - this also improves the basic coordination and balance of the athletes involved. This can be modified further by requiring the ball to be caught with only one hand, alternating hands, hands and feet, by adding more than one ball etc.

## 5. SPRINT-SPECIFIC ACTIVITIES

Medballs are also useful in sprint-specific training exercises. Conditioning sprint work can be more enjoyable for an athlete if medballs are incorporated into the program.

## Training Drills

1. In the "chest pass and sprint" activity, an athlete stands with the ball at chest height, performs the initial part of a standing long jump, and attempts to push the ball as far as they can. Immediately following the explosive jump, the athlete sprints after the ball, concentrating on body position and usually on stride rate (cadence). This activity can be repeated with good recoveries between repetitions (speed and power
development) or can be performed with only walk-back recovery, and becomes a very specific muscular endurance-training session for sprint and power athletes. In its endurance form, this activity is usually performed after all the quality training has been concluded in any training session.
2. The above exercise can be modified so that the athlete tosses the ball like a caber and sprints after it, or releases it after rotating (like hammer throwing) and then sprints. I have added other components to this, such as requiring the athlete to land in a push-up position after the throw, perform 1-2 push-ups, and then sprint out of this position to the ball. The variations on these exercises are only limited by a coach's imagination. I use these exercises after most sprint and power sessions. If an athlete is looking flat during a session, I use these exercises to supplement training once I stop the athlete's high-intensity work. This training is good for basic conditioning and for strength endurance in specific muscle groups such as the hip and knee-extensors. I also use this session (named power-speed) in the general preparation phase (see Chapter 15 for more information on this topic) as a way of "keeping in touch" with speed and power during the increased volume phase of the year.
3. In a team situation I have used medballs as part of a relay. The athletes in each team have to hold the balls in certain positions (e.g. overhead, out in front of the body etc) and run to a certain spot. Upon placing the ball down they run back and the next athlete has to sprint out and retrieve the ball in the same fashion. Once again the variations on these activities are only limited by your creativity.

Visit the following webpage for a range of Medicine Ball Ideas. http://www.faccioni.com/fcubed.html

## Coaching Implications

1. Medball training allows for the efficient transfer of strength to speed and power movements.
2. Medball training can be incorporated into general strength and sport-specific training sessions.
3. The new rubberised medballs can be used in any environmental conditions (I have seen them used by swimmers in a pool).
4. Medballs allow a coach to increase the range and repetition of abdominal exercises undertaken by an athlete during a training session, without straining the athlete's enjoyment of the session.
5. Medballs can be put to excellent use as part of dynamic warm-up routines.
6. Medball training provides ideal strength development prior to an athlete being introduced to a weight room.
7. There is no minimum age group to which the use of medballs can be introduced - I have my 5-6 year-olds use these balls weekly.
8. Medball exercises help improve an athlete's total body coordination, which is more important than raw strength if uncontrolled.
9. Medballs can help make conditioning sprint work more enjoyable.
10. Medballs can be used for both strength and power development work.

## Chapter 10:

## RESISTED SPEED TRAINING

As discussed in Chapter 3 (The Kinematics Of Sprinting), running velocity is determined by multiplying stride rate and stride length. The goals of speed training are to increase the physical, metabolic and neurological components that are essential to increasing an athlete's running speed. In order to improve running or movement speed, the athlete should perform a variety of exercises that are movement-specific and near to the competition rate of movement.

Maximal speed training (at $100 \%$ intensity) must be performed regularly but even this training modality, if performed too regularly, can lead to a speed plateau, making continued speed improvement very difficult. To ensure this plateau does not occur, the athlete should use specific speed-development exercises. These can be divided into two major groups: those of assisted speed exercises which allow the athlete to increase speed or frequency of movement (see Chapter 11 for more information on this topic), and resisted methods which cause an increase in the force required to run at speed. Resisted speed exercises recruit more muscle fibres and promote greater neural activation during a speed performance, which is then transferred to the non-weight-resisted competitive situation.

## 1. RESISTANCE TRAINING

Any athlete wishing to increase running velocity must overcome the inertia of the body through the acceleration phase. In this phase, it is the strong extensors of the hip (gluteals and hamstrings), knee (quadriceps) and ankle (gastrocnemius and soleus) that are actively involved.

Kinetic analyses of sprint performers, focusing on hip, knee and ankle-joint forces, have concluded that the hip-extensors produce the greatest force. Therefore, to maximise horizontal velocity in both the acceleration and top running velocity phases, it is the hip-extensor muscle groups that must be targeted by resistance training to increase their force output.

A second component of sprinting performance that can be targeted by resistance training is the minimising of the drop of an athlete's centre of gravity with each ground contact. The athlete's centre of gravity should not sink too low during the ground-contact phase. The stronger the extensor muscle groups in the lower limbs (gluteals, hamstrings, quadriceps, gastrocnemius and soleus), the less the drop in the athlete's centre of gravity during the ground-contact phase. The less flexion of these joints, the greater the stretch reflex that will be activated, resulting in greater concentric contraction during the driving phase of each stride.

It is from a sound strength base that the speed-strength components of explosive and reactive strength can be developed, through movement-specific training regimes using a variety of different methods designed to increase the stress placed upon the major extensor muscle groups. The increased production of force by these muscle groups is then transferred to greater stride length which, when combined with an optimal stride rate, will lead to an increase in horizontal velocity (in $\mathrm{m} / \mathrm{sec}$ ).

## 2. WEIGHTED-VEST EXERCISES

The weighted vest usually takes the form of a sleeveless jacket that contains several pockets into which weights can be placed, thereby increasing the bodyweight of the wearer. Strength research has looked at the effect of increasing the bodyweight (by 7$8 \%$ ) of sprint athletes over a three-week period, training 3-5 sessions per week. Squat jump performance improved from 42.9 cm to 47.4 cm and, as the relationship between maximal running velocity and squat jump is quite strong, the increased loading would've had a positive effect upon force production and therefore running speed.

A significant benefit of the use of the weighted vest in running is that the added mass increases the vertical force at each ground contact. This increases the stress placed on the reactive strength (stretch-shortening cycle) function of the muscle and improves muscle stiffness at ground contact. This also improves the muscle's capacity to tolerate greater stretch loads, store more elastic energy, and increase power output, which may be observed in a sprint performance as an increase in stride length.

## Training Drills

1. A weighted vest $(3-5 \mathrm{~kg})$ is worn whilst an athlete performs a series of sprint efforts. (I have witnessed athletes wearing a weighted vest whilst performing 300 m runs!)
2. A weighted vest is worn during any form of bounding training (suggested only for very conditioned athletes - bounding itself is very hard on the musculoskeletal system).
3. A weighted vest is worn whilst an athlete runs or jumps uphill, up stairs, on sand, performs sprint drills etc.

The best adaptation will occur when use of a weighted vest is alternated intermittently with exercises where no weighted vest is worn. For example, one set with the weighted vest, one set without.

## 3. WEIGHTED-PANTS EXERCISES

Weighted pants are designed to have small weights (approximately $250-500 \mathrm{~g}$ ) inserted into pouches in the legs. The athlete wearing them then performs a variety of running and jumping exercises. The main benefits to be gained from this training device are that the hip-flexors and supporting muscles get a very tough work-out (especially if the athlete is asked to perform high-knee running or associated drills) and the load is now taken off the spine (which is the problem associated with use of the weighted vest).

Weighted pants can be used in all of the activities suggested in the preceding Training Drills section. Following a training phase with the weighted pants, athletes will find it easier to maintain hip-flexion during subsequent sprint activities. These pants can be used for almost any training element as the amount of weight can be easily controlled. The pants fit firmly and do not move around much, even during a fast sprint. These pants are also of benefit when the athlete is performing hip-mobility exercises (e.g. Remi drills) (see Chapter 14 for more information on this topic), as there is an increase in the strength levels required when performing hip-flexor and hip-abductor activities with an increased load.

## 4. UPHILL RUNNING



A biomechanical study of maximal running up a $3^{\circ}$ incline found the running velocity to be slower than that of running on level ground $(8.35 \mathrm{~m} / \mathrm{sec}$ compared with $8.85 \mathrm{~m} / \mathrm{sec}$ ) and that biomechanically the subjects performed the runs with shorter stride lengths and longer ground-contact times. It was concluded that uphill running increases the stress placed on the hip-extensor muscle groups as the athlete attempts to maximise stride length, therefore increasing this component on a flat surface.

This training method may also lead to shorter ground-contact times if the athlete emphasises fast push-off to conquer the effects of the positive grade. An incline of greater than $3^{\circ}$ will still be beneficial in developing the forceful hip-extensor movements required but will be less relevant in the simulation of the specific technical movements of the sprint action.

## Training Drills

With uphill running there is a dual focus, on correct technique whilst overloading the body, and on emphasising speed of movement and strong extension through the hip region.

1. The athlete should perform incline sprints whilst aiming to maintain correct technique through the total run. To allow this to occur, the incline should be no more than $2-5^{\circ}$ and the distance no greater than 100 m , eg $6 \times 60-100 \mathrm{~m}$.
2. An athlete is required to sprint up an incline at the $5-20^{\circ}$ level. This requires less emphasis on quality sprinting technique and forces the athlete to work harder with their arms and, more importantly, on greater hip-extension with each stride. Due to the quality of effort required in this type of training, the distance should be kept short (20-40m) and each run should be performed at $100 \%$ intensity, e.g. two sets of $4 \times 20-$ 40 m .

## 5. RUNNING ON SAND \& IN WATER

Whilst sand and water environments are ideal for increasing the resistance placed upon a running athlete, they both have limited application in increasing stride length (through the use of the hip-extensors). The resistance in running in these two conditions leads to a greater activation of the hip-flexors rather than the hip-extensors. When running in shallow water ( $20-30 \mathrm{~cm}$ deep), the main emphasis is on getting the leg out of the water (focus on hip-flexor activity). When running on soft sand, the ability to apply great extension force is diminished, and the increase in speed results through an increase in stride rate via a shorter stride and faster hip-flexion activity (all beach-sprint athletes have very high stride rates and short stride lengths).

Whilst not having much of an effect upon the stride length of a sprint performance, this mode of training may have a positive effect upon the second component of sprint performance, that of stride frequency. Running on sand or in shallow water forces the athlete to improve this aspect of their sprint performance. In any sprint performance, it is a lack of stride frequency that is the major limiting factor in ultimate speed potential, so these modes of resistance training may lead to a positive development of speed through improved stride frequency rather than an increase in stride length.

## Training Drills

1. In soft sand, an athlete completes $6-10 \times 10-40 \mathrm{~m}$ sprints with $100 \%$ effort.
2. In shallow water ( $10-30 \mathrm{~cm}$ ), an athlete completes $6-10 \times 10-30 \mathrm{~m}$ sprints with $100 \%$ effort.

## 6. RESISTED TOWING

Towing a sled, tyre, Speed Chute or other weighted device over set distances is a method frequently used by athletes to develop running speed. The reasoning behind these methods is to increase the movement resistance, which requires the athlete to increase force output (especially in the hip, knee and ankle-extensors) to continue to run at speed.

The weight to be used in towing should rarely exceed $10-15 \%$ of the athlete's bodyweight, e.g. an athlete who weighs 70 kg should use a maximally weighted sled of approximately 10 kg . A load greater than this can lead to the athlete changing body position, forcing a sacrifice in running technique. Also, it is important with this type of specific strength training that the dynamics of the movement are such that they do not vary greatly from what is required in the non-resisted sprinting movement. If the weight is too heavy (examples of athletes towing cars around car parks have been documented!), the athlete will be performing more of a maximal strength program which could place undue stress upon the Achilles tendon, knee and hip region. Also, the speed of movement is important with this type of training (power development), so performing very heavy, slow towing activities will result in minimal transfer to the acceleration process needed in the athlete's sport.

The main towing methods used in Australia involve the sled and the Speed Chute. A benefit of using a sled is that it can be easily designed to allow weights to be secured, allowing variation in resistance. It is also very portable and can usually be dragged across almost any surface (I have attached a carpet bottom to one so netballers and basketballers can use it indoors). It is important to have a long attachment on the sled $(5 \mathrm{~m})$ as shorter attachments can result in the sled bouncing along the ground instead of sliding smoothly as the athlete increases speed.

The second method of towing, involving use of the Speed Chute, requires a combination of small parachutes (the exact combination depends on the amount of resistance needed). The advantages of this device are that it is easily transported, the chute size can be changed very quickly, and the chutes can be easily released midflight, allowing the athlete to finish a repetition with no increased resistance and giving the athlete the sensation of greater speed. One disadvantage is that the chutes do not stay directly behind the athlete during the repetition - they move about from side to side (even more so in windy conditions) and can make it very difficult for the athlete to run at any great speed as he or she is trying to keep their balance throughout each repetition. This may be of use to team-sport athletes who are attempting to sprint whilst having to dodge and weave between opposing players, but for the strict purpose of increasing running speed, this is a limitation.

A third towing technique involves the use of resistive rubber bands, which are attached between the coach and one or two athletes. This type of training is good for improving the first few steps of a sprint performance as the athlete is restrained, forcing them to apply a large force to the ground to try to overcome the resistance. These resistive bands can be modified slightly with a mechanism that allows the coach to release the athlete mid-run, resulting in a very fast take-off.

The feeling of extra speed following a resisted run occurs because during the run the athlete has activated many more motor units (nerve and muscle fibres) than are required in the unassisted state. When the resistance is suddenly released these extra motor units continue to fire for a short period, allowing the athlete to apply great force to the track and to rapidly accelerate. (This may have happened to you sometime when you have gone to lift a milk carton you thought was full but it wasn't and you emptied the remaining contents over yourself!).

## Training Drills

1. A towing device can be used by an athlete over $10-30 \mathrm{~m}$ to improve the first part of the acceleration phase. During these repetitions, loads can be up to $10-15 \%$ of the athlete's bodyweight. For example, $4-6 \times 20-30 \mathrm{~m}$ at $100 \%$ intensity with $1-2 \mathrm{~min}$ between each run.
2. Sled work over $30-60 \mathrm{~m}$ is great for improving the transition of acceleration to maximal running velocity. Towing device loads should be less than in the example given above so that the athlete can still reach a high maximal running velocity. For example, $3-4 \times 40-60 \mathrm{~m}$ at $100 \%$ intensity with $3-4$ min between each run and a resistance of $5-8 \%$ of bodyweight.
3. I have experimented with sled work over 100 m . The sled must be kept at the $5-8 \%$ resistance level and recoveries kept long enough to ensure that athletes maintain quality technique throughout the repetition (aimed more at improving speed endurance than pure speed).
4. A combination of resisted and unassisted training is a good way of increasing neural output and improving running speed. For example, alternate sled runs (30$40 \mathrm{~m})$ with unassisted runs $(30-40 \mathrm{~m})$, and repeat $3-5$ times. I completed a study in 1994 which looked at the effects of combining resisted with unassisted techniques - I found significant improvements in running speed over distances of $20-60 \mathrm{~m}$ in elite junior rugby league players.

## 7. BOUNDING



This training modality uses a combination of jumps (single and double-leg) to increase the load placed upon the musculoskeletal system. This form of resisted training, commonly known as plyometrics, allows for high-speed movements to take place with small increases in the total resistance to the movement. (See Chapter 13 for more information on this topic)

Light-resistance, high-velocity training leads to a speed-specific enhancement of the neuromuscular system. This enhancement increases the subjects' abilities to move small resistances with speed (such as their own bodyweight), as shown by performance levels in the high-velocity portion of a force-velocity curve (see Figure $10 a)$.


Figure 10a. Change in force-velocity curve for subjects performing light-resistance, high-velocity training

Research has been completed which looked at strength and power attributes following several training protocols (see Figure 10b).


Figure 10b. Change in isometric force-time curves for subjects performing high-velocity, light resistance training vs heavy resistance training (the vertical intersect line at 120 ms represents the maximal time an athlete has to apply force during any ground contact near maximal running velocity)

## Training Drills

1. The athlete is required to perform long alternate-leg bounds.
2. The athlete performs double and single-leg hops.
3. The athlete does hurdle jumps.
4. The athlete does sandpit jumps.

The movements can be dynamic in nature, depending on the phase of training (preparation phase - less intensity; competition phase - more intensity, less volume) and on the training level of the athletes involved. (See Chapter 15 for more information on this topic)

## Coaching Implications

1. The use of resisted speed training techniques will help ensure that a maximal speed plateau is not reached by an athlete.
2. Weighted-vest training increases the vertical load and helps to improve the athlete's ability to resist gravitational forces during sprinting and jumping.
3. Weighted pants are preferable to the weighted vest as all the load is placed around the legs and there is less stress on the lumbosacral region of the lower back.
4. The incline of any hill used for training should be slight (3-5 ) for technique maintenance and steep $\left(15^{\circ}+\right)$ for pure hip-extension loading.
5. The technique an athlete applies to uphill running should emphasise an active arm swing with a strong hip-extension action.
6. Sprinting on sand and in shallow water $(10-30 \mathrm{~cm})$ is great for improving an athlete's stride rate.
7. The resistive loads used during towing should be only $10-15 \%$ of an athlete's bodyweight, to ensure movement technique is similar to movement during competition.
8. The Speed Chute creates lateral resistance whilst an athlete is sprinting, and so is ideal for training team-sport athletes.
9. An athlete's own bodyweight is usually sufficient during plyometrics training for all but the most powerful of athletes.
10. High-speed bounding has been shown to correlate highly with running speed.

## Chapter 11:

## ASSISTED SPEED TRAINING

As running velocity increases from the submaximal to the maximal in elite sprint performers, stride rate and stride length do not increase linearly. As these athletes near maximal running speed, stride length reaches a plateau and stride rate continues to increase. Therefore, in order to improve maximal running speed, most attention should be directed towards increased speed-of-limb movement. Assisted speed training is a way of helping athletes achieve a greater limb velocity during speed training. The assisted method allows all systems of the body to adapt to high-speed movements, which are then transferred to unassisted competitive situations.

## 1. ASSISTANCE TRAINING

Assisted speed training allows athletes to achieve supramaximal running (greater than $100 \%$ intensity), or in other words to create a running velocity greater than that which can be achieved under unassisted conditions. Researchers have found that during supramaximal running there are increases in stride rate, Integrated Electromyography (IEMG, the measure of muscle activation), ground-reaction forces, muscle stiffness, stored elastic energy, and efficiency of muscle contraction and running skill. It was noted that stride rate contributed $6.9 \%$ and stride length $1.5 \%$ to such increases, indicating a significant relationship between changes in running velocity and stride rate from a maximal to a supramaximal velocity. This could be interpreted as being beneficial in sprint training due to the adaptation of human neuromuscular performance to a higher performance level. Speeds above $106 \%$ of maximal unassisted running lead to an increased stride length, which in turn increases the braking phase of each ground contact, resulting in a slower rate of stride. Therefore, the speed achieved through assistance should be only slightly beyond that which the athlete could do in an unassisted state.

IEMG readings have been shown to increase with increased running speed. The IEMG of the gastrocnemius has been documented as increasing sharply $35-45 \mathrm{~ms}$ after ground contact, and reached its maximum at the end of the muscle stretch. It was
suggested that this increase in electrical activity was due to increased input from the stretch reflex. It has also been suggested that the high IEMG activity will increase muscle stiffness during impact.

Increased muscle stiffness is advantageous in the eccentric phase of stretch-shortening cycle (SSC) activity (such as ground contact during a sprint performance) as it can lead to an increased bouncing action through the muscle tolerating greater stretch loads, possibly storing more elastic energy and improving power. Therefore, creating an overspeed environment will further develop the SSC activity of the neuromuscular system, which will in turn improve the efficiency of ground contact in sprint athletes.

Running at supramaximal speeds (100-105\%) resulted in marked increases in horizontal ( 1052 N ) and vertical ( 3481 N ) force production during impact when compared to unassisted values ( 880 N and 2704 N respectively). These forces were due to an increase in distance from foot placement to centre of gravity ( 31 cm ) as compared to unassisted speed running ( 27 cm ), indicating overstriding.

Several runs at a supramaximal velocity resulted in decreased eccentric force values in both horizontal and vertical directions, from 1052 N to 916 N and 3481 N to 3176 N respectively, which was due to an increased stride rate $(4.65 \mathrm{~Hz}$ to 4.69 Hz$)$ and lower forward velocity of the foot before contact $(2.03 \mathrm{~m} / \mathrm{sec}$ to $1.77 \mathrm{~m} / \mathrm{sec})$. Both factors are conducive to fast running speeds in the unassisted running state.

In more general terms, this meant that the athletes were trying to increase the speed with which they placed their lead leg down on the ground, which led to a more efficient foot placement at this supramaximal running velocity. This, again, is believed to contribute to a greater adaptation of the neuromuscular system to higher performance levels.

## 2. ASSISTED TOWING

The two overspeed devices currently available in Australia, the Speed Belt and the Ultra Speed Pacer, both have certain advantages and limitations.

The Speed Belt is valuable in that it allows an athlete to practice starts, accelerations and supramaximal running velocity. For short-distance accelerations, two athletes can be attached to the one device, and for top-speed running, athletes can be towed over distances greater than 100 m . Limitations include the fact that it is quite hard to control the speed with which the athlete is being towed (dependant upon the stretching capacity of the rubberised cord and the pace of the front athlete) and that it is not possible to slow down quickly when at top speed (which may be required if the athlete detects any muscular problems). The rubberised cord is hollow and could easily tear if trodden on by spikes or sharp studs. From personal experience, the cord should only be stretched $5-10 \mathrm{~m}$ greater than its resting length ( 15 m ) to create an adequate towing effect for the rear athlete if supramaximal velocity is required.

The second device, the Ultra Speed Pacer, uses a pulley system that can lead to overspeed sprint running. An advantage of this device over the Speed Belt is that the front athlete does not need to run too hard to give the required effect to the rear athlete, allowing for better control of the towing speed of the athlete. If an athlete feels they are going too fast and starts to pull up, the system has a safety catch that will release to allow the athlete to slow down before encountering muscle strain. The disadvantages of the Ultra Speed Pacer are that it needs to be attached to a solid, immovable object and that you can only have one athlete being towed at a time (though this could be easily modified) over a maximum of 100 m .

## Training Drills

1. The key to using this training modality is to limit the number of runs because of the high intensity of effort $(100 \%+)$ and the fatiguing effect upon the nervous system. Trying to perform this activity in a fatigued state is dangerous - injury is far too likely because muscle contractions are not occurring properly. So, for example, have the athlete perform 4-6x40-60m supramaximal runs alternated with 4-6 unassisted runs over $40-60 \mathrm{~m}$, with $2-5 \mathrm{~min}$ between each run.
2. If longer repetitions are to be used $(60 \mathrm{~m}+)$, then longer rest intervals are required ( $5-8 \mathrm{~min}$ ) between each run to ensure adequate nervous system recovery is taking place.
3. It should be noted that combining assisted techniques with resisted and unassisted techniques in the same training session, or training phase, is acknowledged as the best way of getting the most out of this training modality. For example, perform two resisted runs $(10-40 \mathrm{~m})$ alternated with two unassisted runs ( $10-40 \mathrm{~m}$ ) followed by one assisted run ( $20-40 \mathrm{~m}$ ). This could be repeated 5-10 times in a sprint session.

A potential problem with supramaximal running through the aid of towing devices is that many athletes are initially allowing themselves to be pulled along and are themselves running submaximally, as indicated by decreased stride rate and IEMG. Therefore, of importance to supramaximal sprint training is the instruction of the athlete to run maximally whilst being towed.

## 3. DOWNHILL SPRINTING

A second method of producing supramaximal speed is downhill sprinting. A study analysing maximal sprinting on a $5^{\circ}$ decline detailed an increase in horizontal velocity of $0.5 \mathrm{~m} / \mathrm{sec}$ from level maximal sprinting. This study did not find any increase in stride rate, only in stride length, so the increased velocity is due to this factor alone. This therefore has minimal effect upon the neural system, unlike the other forms of supramaximal sprinting training. This research indicated that a greater decline (more than $5^{\circ}$ ) would lead to an even longer stride length, resulting in increased braking forces and loss of sprinting technique.

## Training Drill

If a shallow enough decline can be found (less than $5^{\circ}$ ), a session can be arranged which is similar to that applicable to the use of the Speed Belt or the Ultra Speed Pacer. For example, 1-2 times per week the athlete performs $4-6 \times 40-60 \mathrm{~m}$ runs, alternating with running on level ground if possible.

## 4. HIGH-SPEED TREADMILL SPRINTING

Another method of training at supramaximal speeds involves the use of a high-speed treadmill. A biomechanical analysis of the use of such a device found that overspeed training was primarily focused on the hamstring muscle group. A significant increase
in peak hip-extensor and knee-flexor torque (force production through these joints) was recorded immediately following treadmill training.

The increase in running velocity led to increased late hamstring activity, which required extra energy to slow the lower leg before each ground contact and ensured the relative velocity of the foot to the ground was still close to zero. This led to the hamstring group being placed under considerable stress and all components of this muscle group were found to be lengthening, i.e. contracting eccentrically just before ground contact.

The muscle component that undergoes the greatest stretch is the biceps femoris and it is here that tears most often occur. To decrease the potential of hamstring muscle damage during maximal sprinting, there should be regular training at supramaximal velocities, which will increase the eccentric load on this muscle group. When placed under stress from unassisted maximal sprint conditions, the angular velocity about the knee (and therefore stress prior to ground contact) will be less, leading to less injury of the hamstring group.

A limitation of high-speed treadmill sprinting may be kinetic differences due to the ground moving horizontally backwards rather than athletes having to propel their mass horizontally forward, which could interfere with the normal sprint kinetics on solid, unmoving ground.

## Coaching Implications

1. Giving athletes the opportunity to experience an overspeed environment can assist in breaking old speed barriers that may have been established by performing too much of the same intensity speed work. Realising what it's like to run "that fast" may also give the athlete a psychological boost and help them to change old motor patterns.
2. Supramaximal speed training should be used during specific preparation for the competition phase.
3. Careful monitoring must take place to ensure that the athlete is not towed at a speed much greater than that which they are capable of attaining in an unassisted situation, in which case the athlete will adopt a poor running position - as soon as the athlete feels they cannot maintain quality technique, the assisted run should be halted.
4. Assisted training during the acceleration phase $(0-20 \mathrm{~m})$ is beneficial in allowing the athlete to move quickly to overcome their inertia and in helping re-program motor patterns for faster acceleration movements.
5. Like all high-intensity training modalities, the volume of assisted training should initially be low and progressive, with the main emphasis placed on maintenance of good sprinting technique.
6. Supramaximal speed training is more beneficial to an athlete if combined with both unassisted and resisted methods of speed development.
7. With the use of a towing device, it must be ensured that the athlete is running maximally at all times, rather than allowing themselves to be pulled along and therefore running submaximally.
8. Downhill sprinting should never be performed on a decline greater than approximately $5^{\circ}$ as poor technique and increased chance of injury will result.
9. As assisted speed training puts great stress on the neuromuscular system, it is suggested that this form of training only be undertaken 1-2 times per week.
10. Regular training at supramaximal velocities will lead to a decrease in the potential for hamstring muscle damage during maximal sprinting.

## Chapter 12: <br> SPEED \& COORDINATION DRILLS FOR SPEED DEVELOPMENT

Whilst it is common practice to use a variety of training drills in many sports, it is not so widely recognised that the use of sprint-specific training drills are important in maximising the athlete's sprint ability. Improvements in strength, power, flexibility and endurance are not enough to maximise speed performance in an athlete. Body awareness and position drills should also be used to equip an athlete with the correct motor patterns required to move at rapid rates.

## 1. SPRINT-SPECIFIC DRILLS

Gerard Mach, the former head coach and high-performance consultant to the Canadian Track \& Field Association, was the first to give track and field-specific sprint drills their current classifications. These classifications are ' $A$ ', ' $B$ ' and ' $C$ ' drills and heel kicks, and each have their own sub-components. For all but certain track sprint athletes, the use of these drills is too specific - too much time is needed to develop the skill correctly for it be of any use to non-track athletes.

For track athletes, the best progression begins with the ' A ' drill, performed whilst skipping and finally during running. The same progression applies to the ' $B$ ' drill, as well as to the less sprint-specific ' $C$ ' drill, which is excellent for developing hip strength.

Learning to sprint has a lot to do with the athlete's ability to feel the correct positions (their kinaesthetic sense). If the above drills are performed correctly and efficiently, they will result in the development of a stable sprinting technique which will then make the process of increasing sprint speed an easier task for both the coach and the athlete. If an incorrect sprint technique is learnt, correction of these errors may take months or even years.

These drills are usually performed over a $10-15 \mathrm{~m}$ distance and are best incorporated either into the warm-up (see Chapter 6 for more information on this topic) or
directly following it. Once athletes are able to master all sub-components of the ' A ' drill, these can then be integrated into the warm-up as just another preparatory activity to training.

## Training Drills

There is only one drill I teach to non-track athletes and this is what I call the modified running ' $A$ ' drill. The emphasis is on improving leg mechanics (helping to decrease hamstring, lower back and hip-flexor injuries) which will improve stride rate and also force application during the sprint motion. Athletes typically assume a backside leg mechanics sprint position which is bad for the above muscle groups. This sprint position increases ground-contact time and decreases stride rate and is not an efficient running technique.

The modified 'A' drill helps teach an athlete to get into the correct sprint position (leg position) and this position is then applied to all forms of sprinting (e.g. acceleration, weaving, dodging etc). The progression of the drill is as follows:

1. Have an athlete practice the drill over $10-20 \mathrm{~m}$ with a slow forward velocity, picking their feet up off the ground fast. The foot of the swinging leg should come up to the knee of the supporting leg.
2. Add a run-through following this $10-20 \mathrm{~m}$ drill segment, where the athlete tries to maintain the same leg mechanics as horizontal velocity increases.
3. Have the athlete try to get into position immediately from a standing start.
4. Apply a variety of start positions, changes of direction etc, all emphasising the correct leg mechanics.

The process of teaching this drill can take $4-8$ sessions depending on the skill level of the athlete involved.

## 2. SPORT-SPECIFIC DRILLS

To be effective in their chosen sport, most athletes are usually not required to run in a straight line but to sprint rapidly sideways and backwards, and to quickly change direction. Once an athlete has mastered the correct leg mechanics, it is important to include as many sport-specific sprint drills in their training program as possible.

Through the use of sprint grids the athlete can develop speed of movement specific to the demands of their sport. These can be performed in a fashion similar to the sprintspecific drills, with the main aim being to improve the motor patterns of the athlete, which in the long term will improve their overall effectiveness whilst competing.

## RUNNING BACKWARDS

There are many sports that require their athletes to run or shuffle rapidly backwards. These movements are quite foreign to all but the gifted few, and regular training will reap great rewards for this particular aspect of sprint training.

## Training Drills

1. Have an athlete sprint backwards, with the emphasis on either short, fast strides or longer strides.
2. The athlete performs a backwards sprint leading to a turn and a sprint forwards.
3. The athlete performs a backwards sprint followed by a sprint forwards (the way they came) on a given command.
4. The athlete shuffles backwards on command.
5. The athlete shuffles backwards and then sprints (either forwards or backwards).
6. The athlete goes from a backwards shuffle to a side-shuffle or side-sprint.
7. The athlete goes from a backwards shuffle to a sprint around cones or other obstacles.
8. An obstacle course is set up, requiring the athlete to run forwards and backwards and to shuffle both backwards and sideways.

The exact movements will be determined by what your sport requires, for example:

- in terms of distance covered;
- the amount of shuffling versus backwards running;
- the amount of alternation of the sprint from backwards to forwards; and
- the amount of backwards versus sideways sprinting or shuffling.

All of the above drills can be modified by using a variety of visual and auditory cues to signal that a change of direction is required.

## 3. DRILLS TO IMPROVE SPEED, AGILITY \& REACTION TIME

There are other types of drills which can be incorporated into training programs to improve various aspects of speed performance, such as the rate of activation of the nervous system, agility (the ability to change direction), and the ability to react to an outside stimulus (e.g. an opponent or a ball).

## Fast Feet

There are many situations in sport where the athlete is required to be light and fast on their feet. This skill can be further developed through the use of several simple drills that the athletes will find challenging and fun.

## Patters

These drills require the athlete to shuffle their feet as fast as possible along the ground, taking as many short steps as possible over a $1-5 \mathrm{~m}$ distance. They can be performed in sets of $3-5$, with a slow walk-back recovery between each repetition. The main aim is to get the athletes to move their feet at a great speed.

Versions of these drills include:

- patter to jump;
- patter to step (sideways, forwards, backwards);
- patter to sprint;
- a combination of all three; or
- have athletes attempt to avoid having their toes stepped on by a partner.


## REDUCING THE GROUND-CONTACT PHASE

There are several drills that can be used specifically to decrease an athlete's groundcontact phase.

## Stiff-Ankle Bounds

As already mentioned, the ability to have stiff ankles just prior to ground contact during sprinting, change of direction, shuffling etc is very beneficial to performance improvement. This type of training also assists in improving the slight plantar-flexion
of the ankle at ground contact, which improves the stretch-shortening cycle (SSC) ability of the ankle at push-off.

The athlete stands with hands on hips and with a voluntary contraction of the midtorso they bounce up and down on the spot (or moving slightly forward), trying to minimise knee-bend and the time they spend on the ground. The key is to have them concentrate on keeping their ankles as stiff as possible, and to use the ankles as a set of springs as they bound. Successful cues that I have used include the notion that they are jumping up and down on a hot-plate, therefore minimal time on the ground is emphasised. These drills can be performed forwards, backwards, sideways, with rotations ( $180^{\circ}-360^{\circ}$ ), and with eyes closed.

## Single-Leg Ankle Bounds

These are the same as double-leg bounds except that the athlete bounds across the floor concentrating on very stiff ankles and short ground contacts during each stride. The athlete can then increase horizontal speed whilst maintaining stiff knees (not straight legs but an angle of approximately $170^{\circ}$ ), which requires even greater use of the SSC through the ankle-joint. This drill is very specific to sprinting in that it emphasises the ankle and the hip-joint, which are the two main joints involved in sprint performance. This type of drill can also be performed laterally, backwards, and with a combination of single-leg/double-leg movements. (See Chapter 13 for more

## information on this topic)

## IMPROVING AGILITY

An added benefit of the jumps that have just been described is that they lead to an increase in agility. Agility may be regarded as the ability to rapidly change direction and is usually measured using two standard Australian tests: the $5-0-5$ and T tests. (See Appendix 1 for more information on this topic) Work I did with basketballers over an eight-week speed development block, with an emphasis on ground contact and body position, led to good improvements in the agility test results of almost all the players by the end of the training period.

This outcome makes sense when you think about what the athlete is attempting to do during these drills, which is to keep the ankle from giving way during each ground contact. During an agility test, one of the important factors is how quickly the athlete can change direction - having stiffer ankles means less time is required for the transition from one direction to another, so agility is improved. This type of training is very beneficial to all court and field athletes, both for individual sports such as squash, tennis and badminton, and for team sports such as basketball, netball, soccer and hockey.

## IMPROVING COORDINATION AND PROPRIOCEPTION

There are many basic drills that can be used to help improve the basic coordination and proprioception of an athlete. These drills can be used by athletes in any age group and at any level of proficiency.

## Speed Ladder Drills

The use of a Speed Ladder (see Figure 12a) is a great means of developing quality speed coordination in an athlete. A number of activities can be performed using this device.


Figure 12a. Sample Speed Ladder feet pattern drills
The above Speed Ladder drills are very helpful in sports like soccer and basketball which have a strong requirement for their athletes to be able to quickly go from a shuffle (defending) to sprinting (if your opponent passes you). Netballers and tennis players also benefit from these drills as athletes in these sports have to be able to rapidly accelerate forwards, backwards and sideways over short distances, to perform lunging movements, and to regain their posture to resume the defence position.

A variation on the Speed Ladder drills is to use a series of low hurdles for speed and agility development (see Figure 12b).


Figure 12b. The use of low hurdles allows for some useful variations of the Speed Ladder drills to be created

The athlete is now asked to complete various patterns set up by the coach. The variations can generally be left up to the coach's imagination, but here are a few examples.
1.


- the athlete takes two steps or jumps between each hurdle and sprints in the middle; or
- a $180^{\circ}$ or $360^{\circ}$ turn can be added before the second set of hurdles is completed.

2. 



- the athlete takes two steps or jumps between each hurdle and they take $1-2$ steps each side of the middle hurdles.

3. 



- the athlete runs/jumps through the first lot of hurdles and then runs/shuffles around one cone; or
- they can be asked to spin before or after the cone to add difficulty to the drill.

4. 



- the athlete tries different feet patterns, e.g. $2,1,1,3,1,3,2,2,1-$ the athlete should only run through each pattern 2-3 times, as once they get the pattern it should be changed to keep challenging their nervous system.


## Medicine Ball Drills

A variety of medicine ball drills can be performed either in the weight room or in a sport-specific situation to improve balance and coordination. (See Chapter 9 for more information on this topic)

## Modified Bounding \& Skipping Drills

These drills are not specifically aimed at any sport but require the athlete to have a good kinaesthetic awareness of their own body and the space around them. (See

## Chapter 14 for more information on this topic)

## Coaching Implications

1. Once an athlete has been taught the basic sprint technique using sprint-specific drills, these are then used as warm-up drills only.
2. Combining forwards, backwards and sideways running leads to heightened body awareness in an athlete.
3. All fast-feet drills should be completed at $100 \%$ intensity once the athlete can perform the drill adequately.
4. Backwards running should be regularly included in training sessions, particularly when combined with a turn into a forward sprint - this is to simulate what happens when an opponent or a ball goes past the athlete and they must turn quickly and chase.
5. Wherever possible, activities should be designed that require athletes to perform fast feet over obstacles whilst running forwards, sideways and backwards.
6. Improved ankle stiffness can help an athlete's agility and speed because of the resulting decrease in ground-contact times.
7. Agility (change of direction) needs to be trained regularly if improvements are to be achieved.
8. With the Speed Ladder and low hurdles, give the athletes plenty of time between repetitions so that the quality of their performance stays at a high level.
9. An alternative to using a Speed Ladder is to use pieces of dowelling placed at intervals along the ground (or raised on cones etc). This set-up allows for variations in the number of objects, the distances between them, and the activities that are performed over these barriers.
10. Once an athlete is able to perform the set task, the set-up should be changed to continue to challenge their nervous system and to have them adapt to changes in the environment regularly (this is what will happen in a competition).

## Chapter 13:

PLYOMETRICS \& SPEED DEVELOPMENT


Plyometrics is a training component involving repeated bounding exercises. Its aim is to improve the body's tolerance of high-impact loads (as encountered in sprinting and jumping) as well as improving force production in the muscles associated with these activities. Sprint athletes can use many kinds of plyometric exercises to increase their explosive strength levels. With sprint training, exercises should be used where ground-contact times are very close to those of sprinting ( $80-250 \mathrm{~ms}$ ) and where the forces are also comparable to (or higher than) those in sprinting - plyometric exercises have been shown to fit the kinematic requirements of sprinting.

As part of a major research project conducted during 1994, the bounding capabilities of Australia's best male 100 m and 200 m sprinters were analysed and compared with their current seasonal 100 m personal-best time. This research highlighted that the best bounders (using high-speed alternate-leg bounding and high-speed single-leg hopping) also posted the fastest 100 m performances. At the time of this study, the alltime number one and number two male sprinters in Australia were also number one and number two in bounding performance. The current Australian record-holder, Matt Shirvington, also has an extensive background in plyometric training.

## 1. INTRODUCTION TO PLYOMETRICS

Sprinters are known to use forward bounding or hopping exercises in training to raise their explosive strength levels. From a practical perspective, these exercises have force-time characteristics similar to those of sprinting.

In a study on the kinematic variables of forwards bounding and hopping - horizontal velocity (HV), stride rate (SR), stride length (SL), ground-contact time (GCT) and flight time (FT) (see Figure 13a) - the resultant ground-contact forces were 28.3$58.3 \%$ greater in the bounding exercises than in running exercises. The stride rate was highest in running but stride length was greater in the bounds.

| Exercise | HV <br> $(\mathbf{m} / \mathbf{s e c})$ | SR <br> $(\mathbf{H z})$ | SL <br> $(\mathbf{m})$ | GCT <br> $(\mathbf{m s})$ | FT <br> $(\mathbf{m s})$ |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Acceleration Phase | up to 8 | 4 | $1.4-1.8$ | $180-300$ | $100-120$ |
| Maximal Running | $9.59 \pm 0.33$ | $4.46 \pm 0.27$ | $2.15 \pm 0.09$ | $101 \pm 10$ | $130 \pm 11$ |
| Maximal Bounding | $8.16 \pm 0.27$ | $3.29 \pm 0.30$ | $2.48 \pm 0.22$ | $120 \pm 7$ | $169 \pm 17$ |
| Maximal Hopping (R) $5.48 \pm 0.34$ | $1.72 \pm 0.08$ | $3.19 \pm 0.24$ | $196 \pm 14$ | $430 \pm 37$ |  |
| Maximal Hopping (L) $5.20 \pm 0.35$ | $1.81 \pm 0.32$ | $2.88 \pm 0.53$ | $200 \pm 10$ | $393 \pm 97$ |  |

Figure 13a. Kinematic variables measured during sprint training exercises
These results suggest that bounding is a good training modality for developing high levels of strength in the appropriate sprinting muscle groups (calves, hamstrings, quadriceps, gluteals and hip-flexors).

The ability to effectively utilise the stretch-shortening cycle (SSC) of muscle is known as reactive strength. This strength attribute is considered to be a relatively independent strength quality. This means it is possible for an athlete to have high levels of maximal strength and explosive strength but still have poor reactive strength abilities. Because of the short ground-contact times ( $80-250 \mathrm{~ms}$ ) attained by athletes when sprinting, high levels of reactive strength are essential for achieving high running velocities. Sprint-specific strength training should therefore simulate the ground-contact times of sprinting (either the acceleration or maximal running phases) and should aim at training this specific strength quality. Traditional alternate-leg bounding for distance reveals ground-contact times of over 200ms whilst high-speed alternate-leg bounds (or sprint bounding) results have been as low as 130 ms .

Therefore, it appears that sprint bounding uses relatively short SSC times, making it a suitable training exercise for developing maximal running velocity, while traditional alternate-leg bounding is better for the development of the acceleration phase of any sprint performance.

Bounding is a very good strength and power exercise for sprinting because the training stimulus for strength is high and the muscle activity rate is near that of sprinting. The muscular involvement of the hip and knee-flexors and extensors during sprinting and bounding exercises has been measured. The exercises analysed were alternate-leg bounds and single-leg jumps. Both types of jumps recorded 3-4 times as much thigh muscle activity during the support phase (ground phase) as compared to sprint running. Muscle activation throughout full stride varied greatly between the alternate-leg bounds and sprinting, much more than between single-leg hopping and sprinting. The vertical forces developed in maximal hopping were greater than in maximal sprinting and maximal bounding, indicating that it may be an effective strength exercise in the development of leg-extensor muscles (quadriceps and calves) to sustain the effects of high-impact work.

The kinematic variables that apply to single-leg hopping have also been studied (see Figure 13b).

| Ground-Contact Times | Eccentric Force Production | Concentric Force <br> Production |
| :---: | :---: | :---: |
| 230 ms | 370 kg | 200 kg |

Figure 13b. Kinematic variables measured from single-leg hopping
It was concluded that single-leg hopping was an effective strength training modality for sprinters, one that provided a strong stimulus for strength development. Only athletes with a well-developed strength base are able to perform single-leg hopping with the quality that is required. If the athlete does not have the strength base, excessive knee and hip-flexion results in an attempt to absorb the shock that occurs during this exercise. This increases the ground-contact time of the exercise, changing the emphasis from reactive/explosive strength to maximal strength, which is not the aim of this exercise.

Whilst the correlation between vertical jumps (e.g. the countermovement jump, or CMJ, and the drop jump, or DJ) and sprint performance has been well documented (see Figure 13c), it may be that the knee-extensors (quadriceps) and hip-extensors (hamstrings and gluteals) are of importance in both vertical jump and sprint performance. In the sprint performance, the strong knee-extensors will limit collapse at ground contact with each stride and the hip-extensors will help propel the body over the grounded foot and into the next flight phase.


Figure 13c. Interrelationships between major sprint and bounding variables ( $r=$ How related one factor is to another. All values are out of a maximum of 1.00. The closer to 1.00, the greater the relationship between the two variables. The thicker the line between two variables, the better the relationship)

Research has also shown that sprint and jump training influence the rapid neural activation of the trained muscles, leading to increased development of explosive strength (see Figure 13d). Both sprint and jump training are types of explosive strength training which move the force-time curve to the left (increased rate of force development - graph on the left) and raise the force-velocity curve at the velocity end (graph on the right).


Force-Time Curve


Force-Velocity Curve

Before Power Training<br>After Power Training<br>Figure 13d. Force-time and force-velocity curves before ana after power training

One of the benefits of jump training is that it will improve the muscle-stiffness required for force generation. This stiffness improves the muscle's ability to utilise the SSC when moving from the eccentric phase to the concentric phase. Relating this to sprint performance, the greater the stiffness, the greater the muscle's ability to sustain high-impact loads. This can lead to reduced ground-contact times, greater force output during this time, and therefore faster running velocity. This mode of training also improves the athlete's kinaesthetic sense of how quickly they get off the ground, which is one of the more important factors when attempting to improve an athlete's running speed.

It has been frequently stated in the literature that plyometrics should only be attempted by athletes with "advanced" training backgrounds and strength levels. But the reality is that children as young as 4-5 years of age can start learning correct plyometric technique, and as long as the volume of jumps is kept low and the surface used is forgiving (e.g. quality grass surface, a mat on a hard surface), plyometrics can only benefit a young athlete's speed and power development.

## 2. PLYOMETRIC TECHNIQUES

Plyometric training can be divided into several types, beginning with exercises that are low-stress and emphasise minimal ground-contact time, and progressing to exercises that aim to place great stress upon the sprint-specific musculature which, when used in a sprint effort, will lead to a superior performance (see Figure 13e).

| Plyometric Type | Sets per Session | Repetitions per Set |
| :--- | :---: | :---: |
| Low-Impact Reactive Jumps | $10-20$ | $10-20$ |
| Double-Leg Jumps | $3-8$ | $6-10$ |
| Alternate-Leg Bounding | $3-8$ | $6-10$ (each leg) |
| Single-Leg Jumps | $2-6$ | $4-10$ |
| (Horizontal) |  |  |


| Single-Leg Jumps (Vertical) | $2-6$ | $4-10$ |
| :--- | :---: | :---: |
| Shock/Depth Jumps | $2-3$ | $3-4$ |

Figure 13e. Types of plyometric exercises, with sample sets and repetitions (the exercises are listed in order of "hardness" on the musculoskeletal system)

## Low-Impact Reactive Jumps

These jumps are the initial learning plyometric jumps that I would include in a beginner athlete's plyometric program. They can be performed by athletes of any age and training experience, and can be modified by using a skipping rope to perform the activity. The required technique is to have the athlete hold their mid-torso tight (tight stomach muscles) and to be very stiff through the ankle-joint, with the emphasis on making the ankle act like a spring. The athlete is to have minimal knee-bend during each ground contact and they should attempt to pull their toes up and land on the balls of the feet. This exercise is great for decreasing time on the ground, and from experience is very helpful in improving running speed and agility through increased ankle stiffness.

This drill can be modified so that the athlete performs stiff-legged dollys, whereby the athlete runs along the ground with stiff knees (bent at approximately $170^{\circ}$ ) and attempts to maintain stiff ankles throughout the full stride. This could also be turned into a race between athletes.

These drills are best performed on a hard surface such as a sprung wooden floor, running track, on an acromat over a hard surface, or on a well-carpeted floor. Most grass surfaces are not adequate as they allow too much shock absorption, which is not beneficial during this drill. Bare concrete or bitumen surfaces are too hard and should always be avoided.

## Double-Leg Jumps

The next level of plyometrics jumps is the double-leg jump. In this activity the athlete performs a series of jumps with both legs and attempts to:

- get the body as high as possible;
- get the knees to the chest; and
- perform the activity with minimal ground-contact time (keeping ankles stiff and toes up).

This activity should initially be performed on a grass surface, which will absorb some of the shock. More advanced athletes can perform this activity on harder surfaces, such as sprung wooden floors, acromat-covered concrete, or well-carpeted areas. It is important that the athlete maintains a solid upright torso and does not bend over with each jump to maintain balance. The jumps can initially be performed with less intensity, until the athlete is able to maintain the correct posture during maximal efforts.

To make the jumps more enjoyable, they can be performed over several objects such as hurdles, boxes, balls, in fact anything that the athlete is able to concentrate on whilst performing the activity. This activity can be further modified to suit a particular sport by having the athlete perform the jumps backwards, sideways, or by a combination of forwards, sideways and backwards movements.

The total number of jumps in each set should be kept small (see Figure 13e). Six to ten jumps per set is the maximal amount that I would set for all but the most elite athletes.

## Alternate-Leg Bounding

This plyometric activity is the first that requires the athlete to jump on a single leg with any real force. To ensure that the amount of stress placed on the body is minimal, the movement must be more horizontal than vertical. This activity requires up to 40 metres of space in which to be performed.

The emphasis on technique is somewhat different in this drill as compared to the first two. The athlete should be concentrating on an active arm swing, getting a good push off the ground with each stride, and getting the thigh of the front leg parallel to the ground to have as much pause between each stride as possible (float between strides). There is less emphasis on minimising ground-contact time (this is still early in the learning phase - later, ground-contact time and speed of movement become very important) and much more emphasis on an active ground contact with maximal pushoff with each stride.

This drill is aimed at improving the athlete's ability to push off the ground with each stride. Due to the single-leg nature of the drill, there is greater stress placed upon the ankle, knee and hip musculature, leading to increased strength in these regions.

This drill can be modified in the following ways:

1. The emphasis can be on the distance achieved with each stride; this generally leads to the athlete performing the drill faster.
2. The emphasis can be on the height achieved with each stride; the drill is thus slower and greater stress is placed upon each leg as the athlete is falling from a greater height with each stride.
3. The drill can be performed on a hard surface (wooden floor, track) with the main emphasis on speed of the movement. This is commonly known as high-speed alternate-leg bounding. Research has shown that this activity is highly related to the elements of maximal sprinting and is therefore a very specific training drill for the speed athlete. Again, this activity requires a good plyometric technical base to be performed with the speed of movement that is required.

## Single-Leg Jumps (Horizontal)

An athlete who is able to perform the first three types of jump drills regularly in training may then have the conditioning to be able to move on to the next series of drills, which are quite advanced and require well-conditioned and injury-free athletes.

The first of these, single-leg jumps (horizontal), are a variation on the alternate-leg bounds in that the athlete is moving horizontally (quite rapidly). But instead of alternating legs, they are continually landing on the same leg. This greatly increases the stress placed upon each leg and should only be done in small volume, and again only with well-conditioned athletes.

The technique requirement for this drill is that the athlete attempts to perform repeated jumps on one leg, with the knee of this leg being brought to hip height between each jump. This is much more demanding than traditional schoolyard hopping, as performed in a game of hopscotch. Stress placed upon the ankle, knee, hip, and largely on the mid-torso region (to maintain correct hip-positioning) is greatly increased.

This drill should initially be performed on a good grass surface, but as adaptation occurs it can then be transferred to more solid surfaces as have been discussed above. The harder the surfaces, the greater the overall stress on the ankle, knee, hip and back, so this transition must be a gradual one.

## Single-Leg Jumps (Vertical)

Having an athlete perform this drill with an emphasis on the vertical height achieved, rather than horizontal distance, can further increase the stress on the musculature. The technique is similar to that used in horizontal single-leg jumping but with a greater emphasis on jumping upwards rather than forwards. This can be reinforced by having the athlete perform these jumps over obstacles such as hurdles, initially placed very low and gradually raised as the athlete's jumping ability improves. Emphasis must be on short, quality ground contacts with each jump - if ground contacts increase dramatically, the drill must be terminated.

Elite-level athletes have been known to perform this exercise over hurdles placed 150 cm apart and 114 cm high.

## 3. ADVANCED PLYOMETRIC TECHNIQUES

The following plyometric activities are labelled "advanced" due to the high stress levels placed on the musculoskeletal and nervous system of any athlete who performs them. It is recommended that athletes have a minimum of two years of plyometric and strength training behind them prior to performing these advanced activities as a regular part of any training program. I would suggest that an athlete should not be allowed to perform these activities until they are highly competent at single-leg jumps.

## Shock Jumps \& Depth Jumps

Shock (or drop) jumps and depth (or reactive) jumps are fundamentally strength jumps that are not sprint-specific but which do improve the athlete's strength base, allowing for better transfer of strength to speed of movement. These jumps require the athlete to step off a box (of predetermined height) and in the first instance to tense just
prior to ground contact, land with both feet, and absorb all the force with minimal knee-bend. The athlete should be concentrating on stiff ankles and a strong mid-torso just prior to stepping off the box. The height of the box should be $40-120 \mathrm{~cm}$, depending on the training background of the athlete. This type of activity can prepare an athlete for the more stressful training jump, the depth jump.

The depth jump requires the same set-up as the shock jump but a major difference is that when the athlete reaches the ground, they are to rebound upwards as quickly as they can. This places great stress upon the body (especially ankles, knees, hips and lower back) and the jumps should be performed from low heights to begin with. (You might be interested to know, however, that athletes from some eastern European countries have been recorded jumping from heights of 3.2 m !)

The following test can be used to determine an athlete's ideal drop height:

1. The athlete jumps off a series of boxes of different heights, with the height achieved after rebounding off the floor recorded in each case.
2. Once the height achieved from the rebound starts to decrease, it is known that the athlete has reached (or in this case surpassed) their optimal jump height. The optimal jump height is that which leads to the best combination of force production and minimal ground-contact time (important in sprinting). Above this height, the forces are too great and the body starts to inhibit itself, leading to poorer performance and increased stress upon the joints.

The athlete is now able to train at the height that will lead to the best overall result in regard to the height achieved and the stress placed upon the body (see Figure 13f).


Figure 13f. Determining an athlete's ideal drop height
Once this optimal height is determined, the athlete should perform a minimal number of jumps. A typical program from this point on would be three jumps per set and maybe 2-3 sets in total. The more advanced the athlete, the greater the stress they can apply to their bodies and therefore the more jumps per set.

## Countermovement Jumps

Another valuable jumping exercise for sprint development and testing is that of the countermovement jump. This jump takes the form of a two-foot take-off from a standing position. The athlete places their hands on their hips, quickly drops into a squat position, and jumps as high as they can immediately following the squat. It has been shown that there is a strong relationship between height achieved during the vertical jump and running speed, so this training drill is valuable in improving explosive power and sprint speed.

## Coaching Implications

1. Plyometrics are an important component in developing specific explosive power for speed and jumping movements - not surprisingly, the two all-time fastest male 100 m sprinters in Australia are also high-level plyometric performers.
2. Plyometrics result in a decrease in ground-contact time and an improvement in basic coordination and proprioception, all of which is highly beneficial to speed performance.
3. Single-leg hopping has been proven to be a very effective strength training modality for sprinters.
4. Jump training will also improve an athlete's kinaesthetic sense of how quickly they are leaving the ground, an important factor in improving an athlete's running speed.
5. Contrary to current belief, children as young as $4-5$ years of age (i.e. without a specific strength background) can begin basic plyometric training. Total volume and intensity must be set to an appropriate level for all athletes concerned.
6. Alternate-leg bounding has force characteristics similar to that of sprinting, making it a good training modality to help increase sprint-specific strength attributes.
7. Single-leg jumping should not be used extensively by an athlete until they have developed high technical proficiency in low-impact reactive jumps, double-leg jumps, and alternate-leg bounds.
8. Shock and depth jumps should only be used by advanced senior athletes, and should never be performed from heights greater than 1-1.25m.
9. "Less is more" is the principle that should be applied to plyometric training - as soon as the quality of the jumping decreases, the session should be ended.
10. The heights reached during the performance of countermovement jumps can ultimately be strong determinants of running speed.

## Chapter 14: <br> STRENGTH TRAINING TO IMPROVE SPEED PERFORMANCE

If there is a transfer of strength to the sprint technique, the stronger athlete (stronger in terms of sprint-specific muscles) will usually out-perform the weaker athlete. Usable strength (particularly strength gains from a weight-room environment that transfer to the sprint performance) is probably the most dominant factor in the longterm success of any athlete who wishes to continue to improve their basic speed.

Strength training can take many forms. In this chapter I will focus on the different types of strength training that will have a positive effect on speed performance.

## Basic Training Terms

Two of the fundamental terms used in the context of training routines are:

1. Repetition The number of times an exercise is repeated in a given set.
2. Set The block of time in which a particular exercise is performed.

So for example: $\quad 3 \times 10=3$ sets of 10 repetitions.

A rest and recovery period should take place between each set to allow the muscles to recover. The length of this recovery period is dependent upon the intensity of the exercise the athlete is performing. The heavier the load, the longer the recovery between sets. The typical range for recovery times between sets is $1-5 \mathrm{~min}$. If unsure, allow the athlete enough rest that ensures they are able to perform the next set correctly (the trial and error approach).

## 1. KEY MUSCLE GROUPS

Before a coach can develop a strength-training program to improve running speed, they need to have a good understanding of the major muscle groups involved in maximising sprinting speed. As outlined in Chapter 5 (Training Components), the key muscle groups which are required in sprinting are as follows:

1. Calves and tibialis anterior - the muscles which help to minimise the ground contact with each stride and to maintain a dorsi-flexed ankle during stride recovery.
2. Quadriceps - the muscles which help minimise the collapse through the knee during each ground-contact phase.
3. Hip-flexors - the muscles which help the leg to quickly move from each ground contact back to the position in which it is ready for the next stride.
4. Hip-extensors (hamstrings and gluteals) - the major "sprint muscles"; these muscle groups are the "engine" which drives the athlete's body forwards.
5. Abdominals (rectus abdominus, internal and external obliques, transverse abdominis) - the major mid-torso stabilising muscles, important for fast dynamic arm and leg movements.
6. Erector spinae - another group of mid-torso stabilising muscles.
7. Shoulder-flexors and extensors - the muscles regulating powerful arm drive.

## 2. GENERAL STRENGTH TRAINING OUTSIDE THE WEIGHT ROOM

It is possible for juvenile athletes ( $8-15$ years of age) to develop quite high strength levels without attending a weight-training facility. One of the first strength qualities I believe athletes should possess is that of their own bodyweight strength, or in other words the ability to lift one's own bodyweight repetitively during exercise. A number of exercises, all of which have many possible variations, can help in improving this strength, including:

- push-ups (close and wide grip);
- dips;
- chin-ups;
- sit-ups;
- lower and upper torso exercises (with/without medicine balls etc);
- squats;
- jumps;
- lunges; and
- calf-raises, walks, isometric holds etc.


The young athlete who develops enough strength to be able to perform these exercises explosively (with speed) will have all the basic strength attributes to enable them to run fast, and to perform more specific weight-training exercises for maximal strength development at a later time.

Sample Body Circuit

| EXERCISE | REPETITIONS |
| :--- | :--- |
| Lunges | $10-15$ (each leg) |
| Abdominals | $15-30$ |
| Push-ups | $10-20$ |
| Squats | $20-30$ |
| Abdominals | $15-30$ |
| Dips | $10-15$ |
| Jump-squats | $10-15$ |
| Abdominals | $15-30$ |
| Chins/Push-ups | $5-20$ |

This circuit can be modified in several ways:

1. Have the athlete perform more repetitions of each exercise.
2. Have the athlete perform the whole circuit two or more times.
3. Increase the number of exercises in the circuit.
4. Change the order of exercises, e.g. overload a body part by performing two or more exercises in a row that target the muscle groups in question.
5. Add a running, cycling or rowing element to the exercises to increase the aerobic component.
6. Increase the recovery time between each exercise to ensure they are being performed in a quality way.

Other exercises that can be added to this program include:

- ankle-bounds;
- skipping;
- abdominal variations;
- split-jumps;
- reverse back-extensions;
- prone super-person position (arms and legs off the ground);
- hip-flexor/extensor raises;
- burpies;
- start-switches; and
- all medicine ball exercises. (See Chapter 9 for more information on this topic)

Once the athlete has developed a good strength base, they can then continue to develop their strength levels through the use of weight-training.

## 3. GENERAL STRENGTH TRAINING IN THE WEIGHT ROOM



My philosophy on the weight room is that this training environment should be used as it was originally intended - for developing high levels of strength in the appropriate muscle groups. This environment is frequently modified to try to develop sportspecific exercises, often falling well short of the appropriate movement mechanics and speed of contractions to be of much use to an athlete in improving strength. This training environment should be used by an athlete to become strong and powerful in the muscle groups needed in the specific activity.

The beginner athlete should adopt an appropriate lifting technique and develop all areas of the body using multi-joint exercises that require many of the body's stabilisers to come into use. The more advanced athlete can start to stress very specific sprint muscles more intensely (less repetitions and higher loads) to help improve power output in these muscle groups.

## Sample Weights Program For The Beginner Athlete

EXERCISE
Leg-press/squats
Bench-press/dumbbell
Calf-raises

SETS
3

3

REPETITIONS
8-12
3 8-12

10-15

| Hamstring curls | 3 | $8-12$ |
| :--- | :--- | :--- |
| Lat pull-downs/prone-rows | 3 | $8-12$ |
| Abdominals | 6 | $20-30$ |
| Back-extensions | 3 | $15-20$ |

## Sample Weights Program For The Advanced Athlete

| EXERCISE | SETS | REPETITIONS |
| :--- | :--- | :--- |
| Bench-press | 3 | $5,4,3$ |
| Prone-rows | 3 | 5 |
| Squats | 3 | $5,4,3$ |
| Jump-squats | 3 | $6-8$ |
| Dead-lifts | 3 | 6 |
| Abdominals |  | $300-500$ |

Alternate exercises for the advanced athlete could include the following:

1. Variations of the bench-press, squat, jump-squat and prone-rows.
2. Reverse leg-press.
3. Specific hip-flexion/extension/adduction/abduction exercises.

## 4. SPRINT-SPECIFIC STRENGTH DEVELOPMENT EXERCISES

Sprint-specific strength training should focus on the muscles involved in stabilisation and force production around the hip-joint (hip-flexors/extensors/abductors/adductors).

## Training Drills

1. The hip-extensors (gluteals and hamstrings) are targeted by squats and jumping activities and therefore extra work is usually not required.
2. The hip-flexors (psoas major, iliacus, rectus femoris) can be developed using a series of exercises I have named Remi drills. These are named after Remi Korchemny, a former Russian track coach who is now based in San Francisco, California, and can be used as part of a warm-up for strengthening the hip-flexor muscle groups. These muscle groups can be further strengthened through use of a cable machine - have the athlete assume a sprint position and perform repeated
loaded hip-flexor movements (the performance of these without holding onto any object increases balance and stabilisation whilst in the sprint position).
3. The hip-abductors (gluteus medius, tensor fascia latae) are a often neglected muscle group that is very important in the lateral stabilisation of the pelvis during each ground contact, or when the athlete is attempting to change direction. In my experience with speed athletes, addressing the conditioning of this muscle group each year has very positive effects on the attainment and maintenance of the correct pelvic and sprint positions. This muscle group can be trained using the Remi drills described above or in a weight room using either a cable machine or, if available, a specific hipabductor machine.
4. The hip-adductor muscles (adductor magnus, longus, brevis, gracilis) are similar to the hip-abductors in that they are involved in the correct stabilisation and positioning of the pelvis during speed movements. These muscle groups should be trained using variations of lunges but can be more specifically trained using the cable machine or a specific hip-adductor machine.

It is important that the hip-abductor, hip-adductor and hip-flexor muscle groups are specifically targeted during the general preparation and specific preparation phases of each training cycle, to ensure that they are able to tolerate the increased forces that athletes will be able to develop as they become stronger and more powerful through correct strength and speed training programming.

## 5. PERIODISATION OF STRENGTH TRAINING

This section will show you the steps involved in developing a periodised strength training program over a full training year. (See Chapter 15 for more information on this topic)

| Accumulation Phase | Intensification Phase | Unloading Phase |
| :--- | :--- | :--- |
| GENERAL PREPARATION SPECIFIC PREPARATION | COMPETITION PHASE |  |
| General strength $\rightarrow$ Hypertrophy $\rightarrow$ Maximal strength | $\rightarrow$ Strength conversion $\rightarrow$ Maintenance |  |

Figure 14a. Periodisation of strength training
Figure 14a details the general principles of periodisation, comprising:

- an accumulation phase (during the general preparation phase, or GPP);
- an intensification phase (during the specific preparation phase, or SPP, then into the competition phase, or CP ); and
- an unloading phase (minimal weight-training taking place) leading into the important part of the CP.


## GENERAL STRENGTH FOUNDATION PHASE

This phase follows the end of the season and is where the athlete works on the total body in a non-specific way. The athlete performs 10-12 exercises with 20-30 sets per session. Repetitions will be in the 8-15 range, with loads ranging from $60-80 \%$ of the maximum. It is during this phase that the athlete develops a strength base on which more specific strength training can be built. This phase usually lasts anywhere from four weeks to two months, depending on the training background of the athlete (the more advanced the athlete, the less time is needed in the general strength phase).

## Sample Program

Note that this program is the same as the sample weights program for the beginner athlete which was detailed earlier in this chapter.

| EXERCISE | SETS | REPETITIONS |
| :--- | :--- | :--- |
| Leg-press/squats | 3 | $8-12$ |
| Bench-press/dumbbell bench-press | 3 | $8-12$ |
| Calf-raises | 3 | $10-15$ |
| Hamstring curls | 3 | $8-12$ |
| Lat pull-downs/prone-rows | 3 | $8-12$ |
| Abdominals | 6 | $20-30$ |
| Back-extensions | 3 | $15-20$ |

As already mentioned, the number of weeks that each athlete spends in the general foundation phase is determined by his or her training background (see Figure 14b). Once the conditioning base has been developed through several years of training, it is of little use to spend much time on general work when specific work leads to much better results. Large volumes of specific work can only be achieved and carried out properly from a well-developed training base.

| Training age | 1 year | 5 years | 10 years |
| :--- | :--- | :--- | :--- |
| Time in GPP | $8-12$ weeks | $4-6$ weeks | $2-4$ weeks |

Figure 14b. Time spent in the GPP as it relates to years of training experience

## HYPERTROPHY PHASE

This phase is different from the hypertrophy training that is a component of traditional body-building. In the development of speed and power athletes we don't want to be stimulating too many slow-twitch fibres. The greater the fast-twitch fibre development, the more powerful the athlete will become. This phase emphasises repetition ranges of 6-10 with the athlete lifting a weight that does not allow them to perform one repetition more than is required. This training stimulates growth in mainly the fast-twitch fibres, further strengthening the musculoskeletal system in preparation for more intense training programs later on in the training plan. This phase lasts from four weeks to 3-4 months depending on the amount of size increase the athlete is after.

## Sample Program

| EXERCISE (pick one exercise from each group) | SETS | REPETITIONS |
| :--- | :--- | :--- | :--- |
| Squats/lunges/single-leg squats/incline leg-press | 3 | $6-10$ |
| Bench-press/incline-press/dumbbell-press | 3 | $6-10$ |
| Shoulder-press/dumbbell shoulder-press/military-press | 3 | $6-10$ |
| Seated row/lat pull-downs/bent-over row/prone-row | 3 | $6-10$ |
| Back-extensions/dead-lifts | 3 | $6-10$ |

This sample program allows for large variations from one session to the next (e.g. using a different exercise in each session). The athlete should perform three sets of 610 repetitions for each exercise.

There is an easy way to work out when an athlete should increase the weight of their lift. Start with three sets of six repetitions at a set weight. As the athlete improves their strength, they should attempt to increase the number of repetitions until they reach the upper limit of 10 . Once they are able to perform three sets of 10 repetitions, this is the signal to drop the repetitions back to six and increase the weight of the lift
accordingly. This way the athlete is constantly challenging their strength system and they have a set procedure for increasing the load.

## Sample Program

Bench-press 3x6 repetitions @ 40kg
Build to $3 \times 10$ repetitions @ 40kg
Adjust to $3 \times 6$ repetitions @ 45 kg

## MAXIMAL STRENGTH PHASE

In this phase, the athlete attempts to maximise their strength with their current body size. This is achieved by improving the neural development of the muscles involved whilst limiting any further increase in muscle size. To accomplish this, the athlete will train with loads of $90 \%+$ with a repetition range of 1-5, and 15-20 sets per session.

Maximal strength training is very demanding on an athlete's body - the length and intensity of this training phase is totally dependent upon the athlete's training background and weights experience. Athletes new to this type of training mode should start with repetitions of five - after several years of this type of training, the repetition range can be decreased to regular sessions of three repetitions. It would be rare for even an advanced athlete to do a full session with very low repetitions. Advanced athletes may work from repetitions of five down to 1-2 and back to five in a single session. This type of training is usually only performed once or twice a week as more sessions would be neurologically too demanding on the body, especially considering the athlete will be performing several other sessions during the week.

The heavier the load, the longer the recovery required between sets and sessions. Between each set, the athlete should be given approximately 3-5min to allow full recovery of the central nervous system.

## Sample Program

| EXERCISE | SETS | REPETITIONS |
| :--- | :--- | :--- |
| Bench-press | 3 | $5,4,3$ |
| Prone-rows | 3 | 5 |


| Squats | 3 | $5,4,3$ |
| :--- | :--- | :--- |
| Dead-lifts | 3 | 6 |
| Abdominals | 3 | $20-40$ |

It is important to remember that the main goal of this phase of training is to maximise the force output of the muscles involved in the sporting movement. Total body strength is emphasised using squats and dead-lifts.

## STRENGTH-CONVERSION PHASE

In the past, the speed athlete has tried to convert strength to power through a weightroom conversion phase. This phase lasted from 4-8 weeks, and consisted of lighter loads to be lifted ( $40-60 \%$ ), medium repetitions ( $5-8$ ), and attempts to move the weight as fast as possible. The problem with this regime was that while the athlete was performing this type of training, their maximal strength levels would deteriorate, limiting their ultimate power levels.

An alternative to this type of periodisation is to integrate the strength-conversion phase with all the previous phases and attempt to convert strength to power and speed continuously throughout the training year (see Figure 14c). This training model has many advantages as it allows the athlete to:

- continue maximal strength development throughout the entire training year;
- gain great strength conversion throughout the training year, and not at one specific phase of the year; and
- become faster and more powerful for more time each year, making them more competitive for longer during the competition phase.

General Preparation Phase | Specific Preparation Phase | Competition Phase


Figure 14c. Continuous conversion of strength to power and speed throughout the training year

This continuous conversion can be achieved through the use of sprints and plyometrics (see Chapter 13 for more information on this topic) throughout the training year. Maximal sprinting over distances of $10-30 \mathrm{~m}$ requires high strength levels and explosive strength attributes for propelling the body quickly over these short distances. These sprint intervals are great for developing explosive power. Plyometrics also require high strength and power levels to be well utilised. Use of this training modality in the weight room and on the field, track or court will also improve the conversion of the strength being gained in the weight-room environment to the specifics of your sport.

## Sample Strength-Conversion Exercises

There are a number of optimal strength-conversion exercises that can be performed in the weight room (see Figure 14d). With these exercises, look to perform 3-4 sets of 610 repetitions during a strength session.

Core Strength Exercise
Strength-Conversion Exercise

| SQUATS | BOX JUMPS |
| :--- | :--- |
| LUNGES | SPLIT JUMPS |
| POWER-CLEANS | HURDLE JUMPS |
| BENCH-PRESS | DYNAMIC PUSH-UPS/MEDICINE- <br> BALL THROWS |
| SEATED OR BENT-OVER PULLS | OVERHEAD THROWS |

Figure 14d. Strength-conversion exercises for weight-room training

## MAINTENANCE PHASE

Once an athlete is in the major part of the CP, they should be focusing most of their attention on the skills, tactics and techniques required by their sport. However, strength levels are to be maintained throughout the entire CP. This can be achieved by doing lifting once a week with near-maximal loads $(90 \%+)$, repetitions of $2-5$, and only 3-4 core exercises (e.g. squat, power-clean, bench-press, jump-squat etc).

## Sample Program

| EXERCISE | SETS | REPETITIONS |
| :--- | :--- | :--- |
| Power-clean | 3 | $2-5$ |
| Squat | 4 | $2-5$ |


| Jump-squat | 3 | 6 |
| :--- | :--- | :--- |
| Bench-press | 4 | $2-5$ |

I believe that the frequent performance of isolation exercises (e.g. biceps curl) during this phase of the year is not conducive to achieving the performance that is required. It is not only time-consuming but at this stage the athlete should be performing all activities as part of a whole-body approach. The core exercises detailed above utilise all the major body components in an active manner.

Maximal strength cannot be maintained indefinitely using the type of training described here. It may be necessary to occasionally increase the number of training sessions to two per week for a 2-3 week block if strength seems to be diminishing. This maintenance style of strength training could potentially last for a 6 -month competition phase.

## Coaching Implications

1. The first strength quality any athlete needs is the ability to lift their own bodyweight.
2. Gymnasts are an example of an athletic group with extremely high strength-toweight (power) levels, yet they rarely do traditional weight-training in a weight room.
3. The weight room should be used as originally intended, as a place to get strong by performing basic exercises - all the sport-specific strength training should be conducted in the appropriate, specific training environment.
4. Many speed and power athletes forget that their main reason for lifting weights is to develop speed and power, not to become strong for the sake of it.
5. As the athlete progresses in training from year to year, less time needs to be spent performing general strength training. Specific strength training becomes a greater priority for more of the training year.
6. When an athlete has developed enough muscle mass, the hypertrophy phase can be removed from the program, leaving more time for maximal strength or power development.
7. During the maximal strength phase, only multi-joint compound exercises should be used, e.g. squat, dead-lift, bench-press etc. Also, the maximal strength phase should only be applied to athletes with a good strength and conditioning background.
8. Repetition ranges lower than five are not recommended for athletes with less than two years of training experience. Connective tissue, joints and the skeletal system are not able to handle the stress of maximal strength training for long periods without a good training base.
9. Combining the maximal strength and strength-conversion phases allows for better conversion of strength to power movements.
10. Continuation of strength training on a year-round basis is very important for female athletes. Because of the lack of naturally occurring testosterone in female bodies, improvement in strength can be a slow process and, once developed, is lost more quickly after a period of non-training (sometimes after only 10-14 days) than in their male counterparts. A positive side of the limited testosterone levels found in female athletes, however, is that muscle mass is less likely to increase substantially, meaning that a female athlete's major strength gains come from the desired neural processes of strength.

## Chapter 15:

## PERIODISATION OF SPEED TRAINING



It is important to integrate speed and power training into all phases of the training year. Many sports traditionally develop quality speed attributes during the competition phase of training but fail to consolidate this development during the preparation phase of training. This type of periodisation of training leads to minimal long-term speed gains, as the athlete is too inconsistent as a result of this training to see any great progression over several seasons. In this chapter I have attempted to explain how the maintenance of speed and power training throughout the training year will lead to better long-term development of such attributes in athletes.

## 1. BASIC PERIODISATION STRUCTURE

A typical training year is broken down into three major training phases, which may themselves be broken down into further subdivisions (see Figure 15a).

Preparation Phase
General Preparation Phase (GPP)
Specific Preparation Phase (SPP)
Competition Phase
Pre-Competition Phase (PCP)

Competition Phase (CP)
Transition Phase

| PREPARATION PHASE |  | COMPETITION PHASE |  | TRANSITION <br> PHASE |
| :---: | :---: | :---: | :---: | :---: |
| GPP | SPP | PCP | CP |  |

Figure 15a. Major training phases in a typical training year
Each phase of training is made up of a number of smaller cycles known as macrocycles, composed of 2-6 weeks of training on a specific element. Each week of training is commonly known as a microcycle, the objectives of which complement those of the larger macrocycle (see Figure 15b).

| MACROCYCLE 1 |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :---: |
| Microcycle | Microcycle | Microcycle |  |  |  |  |
| 1 |  |  |  |  |  |  |

Figure 15b. Example of a six-week macrocycle
The major training phases and their subdivisions each have their own particular set of goals and defining characteristics.

## GENERAL PREPARATION PHASE

This phase of training usually follows on directly from the transition phase (a nonspecific training phase). The main emphasis of the GPP is on general physical development. The basic elements of speed and power development are addressed during this phase. The athlete will be involved in strength training, aerobic and anaerobic conditioning (see Chapter 17 for more information on this topic), flexibility training (both static and dynamic), and generally in increasing the volume of training throughout each macrocycle.

## SPECIFIC PREPARATION PHASE

The SPP directs attention towards the specific conditioning principles that are required to maximise speed and power development. The athlete will be involved in maximal strength training, plyometrics training, and specific speed training. All
associated work is now specific to the demands of the sport (e.g. increase in agility, reaction time and proprioception training).

## PRE-COMPETITION PHASE

The structure of the PCP will begin to resemble how the athlete is going to train and perform during the CP . This is the time when the athlete can start to be involved in trial competitions and practice matches, and when the volume of training decreases whilst there is a concurrent increase in the intensity of the work being performed (see Figure 15 c). This phase is also important to the coach as an opportunity to evaluate the current condition of their athletes and still have the time to make adjustments to the program before the season starts, ensuring the best performances during the season.


Figure 15c. Relationship between volume and intensity during the PCP

## COMPETITION PHASE

The CP is the most important phase of the year, as the athlete is expected to convert the previous 12 months of training into a superior performance. This phase is distinguished by:

- low-volume training;
- high-intensity/game-specific training;
- many more rest/recovery days; and
- the athlete reaching a performance peak around finals time.


## TRANSITION PHASE

This phase provides a break from the rigours of regular, structured training. During this time the athlete should attend to any injuries and maintain a low level of activity (usually performing activities that are not related to their sport - e.g. for running athletes, great cross-training activities would include swimming, cycling etc). For speed athletes, there is no need to work on speed development during this phase. Instead, the athlete should ensure they are ready for another year of training (both physically and psychologically) at the end of the transition phase.

This phase generally lasts anywhere from 2-8 weeks depending on the maturity of the athlete (the younger athlete usually requires a longer transition phase).

## 2. SPEED TRAINING IN THE PREPARATION PHASE

Understanding the reasoning behind the preparation phase will allow you to quickly see why it is important to be performing some form of speed development throughout most of the training year. This phase is all about building basic physiological attributes such as muscular strength, power, flexibility, endurance and speed, as well as improving technique and tactics, and the athlete's understanding of the importance of correct nutrition, recovery techniques and psychological training.

The development of strength and the transfer of strength to power can benefit from the inclusion of a modified speed program throughout all phases of the training year. The preparation phase is the time to maximise each athlete's speed technique so that all increases in strength and power can be quickly transferred to the sprint performance.

With the preparation phase underway, many athletes will be either spending most of their time lifting weights, or developing an endurance base for the more specific training that takes place closer to the competition phase. The inclusion of speed training is important in both situations. The use of speed training during heavy
resistance training allows a movement-specific transfer of strength to any sprint performance. Also, weight training is a relatively slow training modality and the inclusion of speed technique and acceleration work can keep the athlete in touch with the required high limb velocities.

The athlete who performs high-volume aerobic work will quickly decrease their speed potential because endurance training does not train the correct fibre types (fast-twitch) or the correct nervous system pathways for the development of speed. What can happen is that the athlete will be less able to sprint as quickly as they did before the start of an endurance training phase. Even if speed is not a priority, it is important to minimise the decrement that will occur with this endurance training. Speed sessions intelligently scheduled in this training period will decrease the potential losses that may occur in speed base throughout this phase.

This type of training should occur once in each training week when the athlete is relatively fresh, before any taxing work on any particular day. It should also be short (30min maximum) and could used as part of the warm-up routine (see Chapter 6 for more information on this topic). The session could consist of a 10 -minute warm-up, 10 minutes of sprint-specific drills, and 10 minutes of short acceleration work over distances that are specific to the sport in question, e.g. $5-10 \mathrm{~m}$ for tennis and badminton, $10-30 \mathrm{~m}$ for netball and basketball, and $30-50 \mathrm{~m}$ for football, hockey and cricket. This last 10 -minute session should not be rushed. The athlete should be given adequate time between each run, and each attempt should be done at high intensity.

Following are examples of sprint distances and repetitions:

1. Tennis \& badminton
2. Netball \& basketball
3. Football, hockey \& cricket
$5 \times 5 \mathrm{~m}, 5 \mathrm{x} 10 \mathrm{~m}$.
$3 x 10 \mathrm{~m}, 3 \mathrm{x} 15 \mathrm{~m}, 2 \mathrm{x} 20 \mathrm{~m}$.
$2 \times 20 \mathrm{~m}, 2 \mathrm{x} 30 \mathrm{~m}, 2 \mathrm{x} 40 \mathrm{~m}$.

These runs could be incorporated into any skill component applicable to this phase of the year. Each run should be followed by a very slow walk-back recovery, and the further the athlete is asked to run, the longer the recovery between each of these repetitions.

The athlete who is spending a larger proportion of their time in the weight room will benefit from the inclusion of a weekly speed session in several ways:

- this athlete will minimise the loss of speed during this phase (as with the endurance-trained athlete); and
- conversion of strength to power and to specific sprinting speed can be greatly enhanced if the athlete performs maximal sprint training during this phase of training.

This training component could be performed in conjunction with an athlete's strength-training session, with a plyometrics session, or in a session by itself (preceding a skills session). Many successful speed coaches have used a system whereby they have their athletes perform a weights session directly followed by a speed session. This speed session consists of several short acceleration sprints over distances of $10-40 \mathrm{~m}$. In this situation, the athlete lifts heavy weights, and can then have an almost immediate translation of strength into a powerful speed movement.

The use of power-speed activities (e.g. medicine ball drills) is a very good way of increasing speed and power attributes as well as converting weight room strength to power. (See chapters $\mathbf{7}$ \& 9 for more information on this topic)

This consistent approach to speed training (see Figure 15d) will lead to:

- greater power and speed development levels in the athletes involved;
- minimisation of the traditional power-conversion phase (power conversion is now happening throughout all phases of training); and
- less incidence of injury when the athletes move into their PCP, which requires much more in the way of speed movements, because the athlete is never far from speed running through prior training phases.



## Preparation Phase $\longrightarrow$ Competition Phase

Figure 15d. Modified periodic plan emphasising year-round conditioning and development of all training elements

Another typical periodisation speed development plan used in many sports involves the athlete doing lots of distance sprints (all less than $100 \%$ intensive) - as the competition phase gets closer, the distance decreases and the speed of the runs increases. I would like to challenge this way of thinking by suggesting that the athlete does not perform longer distance sprints until their technique is solid at the shorter distances.

Applying this modification to speed and power periodisation means the athlete rarely performs sprints at less than $90 \%$ intensity, as opposed to the longer $70-85 \%$ intensive sprinting which does very little for the neural processes that contribute to the maximisation of speed development in any athlete. This also keeps athletes from "going through the motions" during these types of sessions, where only true track athletes generally have the conditioning background to adequately perform $150-300 \mathrm{~m}$ repetitions with the quality required for it to be beneficial to long-term speed improvement. The typical team-sport athlete will generally struggle to perform these repetitions, leading to runs completed with poor technique, low intensity, and a poor mental state. This is not conducive to the development of speed in athletes.

What is important to remember, as established in Chapter 2 (The Components Of Speed), is that the acceleration phase of sprinting is the most important phase in most
sports. It is the first $10-40 \mathrm{~m}$ that fits the sprint requirements of all but a handful of sports. The development of maximal running speed (such as by performing $60 \mathrm{~m}+$ repetitions at high speed) is of little to no benefit to the team-sport athlete or the court athlete, as they will usually sprint no more than $5-30 \mathrm{~m}$ during a competition. The physiological requirements are also different, so time spent on improving an athlete's maximal running speed will yield little improvement in on-field/on-court performances.

In summary, to minimise a decrease in speed during the strength and/or endurance components of the preparation phase of training, it would be beneficial to maintain speed work throughout this phase. Also, speed training during a strength block can improve the transfer of strength to power and also to the sprint performance, which has a high dependence upon strength at speed.

## 3. SPEED TRAINING IN THE COMPETITION PHASE

The structure of the speed sessions that take place during the competition phase of any sport will vary quite considerably from the structure used in the preparation phase.

## SPECIFIC DISTANCES \& MOVEMENTS

During this phase it is important to get as sport-specific as possible regarding distances and directions covered. Whilst distances are sport-specific during the preparation phase, they are focused more on improving sprinting technique. During the competition phase, all the emphasis should be placed on having the athlete cover the ground as fast as possible in game-simulated situations. Technique should still be monitored, but the athlete should be concentrating on getting from point A to point B as fast as they can.

The usual scenario in many sports is that athletes will begin to sprint forward but will then be forced to change direction, in some cases back towards where they started from. Each sport has its own specific movement patterns that can now be trained at $100 \%$ speed capacity. In each sport there will be certain positions that require
different sprint grids to be set up, e.g. forwards versus backs in football, attack versus defence in netball, wingers versus centres in hockey etc. (See Chapter 12 for more information on this topic)

## TRAINING VOLUME

During the preparation phase, it is adequate to have an athlete perform one session per week. During the competition phase, if the emphasis is on improving speed performance, it is important that an athlete performs more than one session per week. The significant reasons for this are as follows:

1. The best neural adaptation occurs when an athlete is performing these sessions 2-3 times per week.
2. If three sessions are scheduled per week, an athlete tends to focus on them more because they are seen as an important part of the training program, and concentration is better during each session and over the training phase.
3. Three short, intense sessions are better than one or two longer sessions - athletes become less fatigued and less bored with short 20-30min sessions several times per week.
4. Quick results can be had from a short (4-6 week) and intense sprint program using a combination of resisted and assisted training methods.

## 4. USE OF RESISTED AND ASSISTED TRAINING METHODS

During the preparation phase, as the athletes are coming up to their major competition of the year, it is possible through the use of resisted and assisted methods of speed training to have quite a rapid improvement in running speed, which can concurrently be converted to speed movements in different directions if required. A study combining the use of resisted methods of sprinting (see Chapter 10 for more information on this topic) and assisted methods of sprinting (see Chapter 11 for more information on this topic) had rugby union athletes improving significantly over $20-60 \mathrm{~m}$ after six weeks of training. Unpublished research on netball players, taken from a study of sprinting focusing on training techniques similar to those used in the rugby union study, showed significant improvement in $5 \mathrm{~m}, 10 \mathrm{~m}$ and 20 m sprint performances over an eight-week training period. Performances may have been
significantly improved earlier in the study but testing was scheduled for eight weeks after the start of the sprint program. Both studies comprised only two sessions per week and it is believed that with three sessions, results could have been obtained earlier.

Here is the program which was developed for the rugby union players (see Figure $15 e$ ). The resisted and assisted groups alternated training modalities.

| Week | Training: sets x distance (rest period) |
| :---: | :--- |
| 1 | $3 \times 20 \mathrm{~m}(3 \mathrm{~min}), 3 \times 40 \mathrm{~m}(4 \mathrm{~min}), 1 \times 60 \mathrm{~m}$ |
| 2 | $3 \times 40 \mathrm{~m}(4 \mathrm{~min}), 3 \times 60 \mathrm{~m}(5 \mathrm{~min})$ |
| 3 | $6 \times 40 \mathrm{~m}(4 \mathrm{~min}), 1 \times 60 \mathrm{~m}(5 \mathrm{~min})$ |
| 4 | $6 \times 60 \mathrm{~m}(5 \mathrm{~min})$ |
| 5 | $4 \times 20 \mathrm{~m}(3 \mathrm{~min}), 4 \times 40 \mathrm{~m}(4 \mathrm{~min}), 1 \times 60 \mathrm{~m}$ |
| 6 | $3 \times 20 \mathrm{~m}(3 \mathrm{~min}), 3 \times 40 \mathrm{~m}(4 \mathrm{~min}), 3 \times 60 \mathrm{~m}(5 \mathrm{~min})$ |

Figure 15e. Program developed for rugby union athletes comprising resisted and assisted methods of sprinting

The program developed for the netball players required them to complete $5-8$ resisted runs over $5-15 \mathrm{~m}$ with a sled $(5 \mathrm{~kg})$, alternated with $5-8$ unassisted runs over $5-15 \mathrm{~m}$, with $60-90$ sec rest between each run. This session was performed twice a week for a period of eight weeks.

## Coaching Implications

1. The GPP and SPP should be used to develop all the specific strength and power attributes required for speed, whilst the PCP and the CP are used to maximise transfer of the above attributes to speed of movement.
2. During the GPP and SPP, high-speed footwork can be beneficial in keeping the athlete in touch with speed.
3. Care needs to be taken during the PCP as this is traditionally when the focus of training moves from volume to intensity - if both factors are kept too high at the same time for too long, injury or overtraining can occur.
4. The transition phase is crucial in providing a break from the rigours of regular, structured training, and will last anywhere from 2-8 weeks depending on the maturity of the athlete.
5. Speed training should be undertaken year-round so that the relevant neural pathways are continually stimulated.
6. Speed training in the GPP and SPP can be used to help transfer strength to power through repeated explosive movements.
7. If the speed training involves a team-sport or court-sport athlete, it should emphasise the acceleration phase of a sprint performance with no sprints greater than 20-30m (for court athletes) and $30-40 \mathrm{~m}$ (for field athletes).
8. By "keeping in touch" with speed during the GPP and SPP, there is less chance of injury to an athlete during the PCP or early CP , when they are expected to perform $100 \%$ sprints or speed movements regularly.
9. As with plyometrics, speed training works on the premise of "less is more". Less volume with high intensity (all speed work should be completed at 95-100\%) leads to the best improvements in speed development.
10. Combining resisted and assisted training with unassisted training is a very good way of improving an athlete's movement speed.

## Chapter 16:

## SPEED DEVELOPMENT IN PRE-ADOLESCENT CHILDREN

The teaching of correct movement techniques during the important coordinationdevelopment phase of a child's growing years (5-12 years) is important to long-term athletic performance. The main focus of this training should not be the development of speed as such, but rather the development of correct movement patterns, which is vital to future athletic performance. The development of speed in young children also helps develop the attributes of strength, power, agility, coordination and balance concurrently. This will help the child be more successful in the sport of their choice and will improve the chances that they will stay involved in sport into their adult years.


## 1. DEVELOPMENT OF PHYSICAL ATTRIBUTES

During the growing phases of a young person's life, not all physical attributes (e.g. speed, strength, power, flexibility and endurance) develop at the same rate (see Figure 16a).



Figure 16a. Maturation rates of different physical attributes
The aerobic endurance of a child is actually the same as that of an adult in terms of performance values. If aerobic fitness is measured relative to the bodyweight of each individual ( $\mathrm{ml} / \mathrm{kg} / \mathrm{min}$ - millilitres of oxygen per kilogram of bodyweight per minute of activity), the child's aerobic system is equivalent to that of an adult's from approximately six years of age onwards.

A physical attribute of the child that rates well below that of the adult in both absolute and relative terms is that of muscular strength. This attribute is subject to the muscle mass, neural adaptation and hormonal status of the individual. All of the above factors
develop rapidly in post-adolescence, so high levels of strength cannot be realised in the pre-adolescent athlete (see Figure 16b). Both power and speed are greatly determined by the strength level of the athlete, so these attributes are also poorly developed in the pre-adolescent athlete.


Figure 16b. The development of grip strength with maturity (grip strength has been shown to be a good measure of overall body strength)

Following on from this, it is obviously very important to apply as much neural stimuli to the developing athlete as possible to maximise neural speed, strength and power adaptations during the various phases of development. It is also important to carry the flexibility that the child naturally possesses over into their adult life. It is well documented that the average young child is more supple or flexible than the average adult. Connective tissue stiffness and joint stiffness increase as the child matures generally, children are very flexible and will become less so if this is not attended to from an early age.

Many muscle fibres are transitional during the first 10 years of life and can, through external stimulus, function as either fast-twitch or slow-twitch fibres. As discussed in Chapter 1 (The Physiology Of Speed), it is speed and power that are the major physical factors which determine success in many of the sports played in Australia. As speed and power levels are related to fibre type (fast-twitch fibres and the neural system that goes along with this fibre type), it would be detrimental to the athlete to spend a lot of time developing the aerobic system (and therefore slow-twitch fibre
content) at the expense of the more important fast-twitch fibres. From Figure 16a, it can be seen that the development of speed closely follows the rate of development of strength.

Rather than focusing on the physiological differences between males and females, the training of young children can instead emphasise skill acquisition and reinforcement of the basic speed and strength training principles. Time spent developing the aerobic capacity of children cannot be justified due to the high aerobic capacity most children already have from an early age.

In sports that have a high aerobic component (e.g. distance running, cycling etc), speed capacity is important if the athlete wishes to reach a high level of performance. The best aerobic athletes in the world in their respective events still have a great capacity for speed, a capacity which is often what separates the first place-getter from the no place-getter. The development of speed and strength attributes from an early age will allow for a greater work capacity in later years and will increase the chance of maximal performance at the senior level.

This concept has been used in European countries for over 40 years. Children are taken through a very detailed physical education program from an early age (starting in primary school) whereby high levels of skill are acquired and specific strength and speed-conditioning programs are integrated into everyday school activities. This has allowed the training intensities and volumes to be very high when the child is old enough to make the decision to become a competitive athlete, leading ultimately to high performance levels in the child's late teens and into adulthood.

Because of the increasingly sedentary lifestyle our children are leading (due to the proliferation of computer games, television shows, music CDs etc), and with the breakdown of the physical education structure throughout our primary and secondary school system, it is important that the child athlete is exposed to correct strength, speed and power-conditioning principles from an early age. This will ensure that they progress at the rate needed to allow them to make the successful step up to competitive sport whilst limiting the problems associated with high-level training; for
example, over-use injuries, such as soft-tissue injuries which occur as a consequence of performing too much repetitive work on specific muscle groups and joints.

Many researchers have detailed how it is possible for a young athlete to start achieving good strength gains (especially strength gains relative to the child's bodyweight) from as early as eight years of age. These are strength gains that are beyond the natural strength improvements that occur through the normal maturation process. They can be achieved through the use of non-weight-room conditioning methods that will result in great variation in training and will lead to the appropriate physical development of the child. (See Chapter 14 for more information on this topic)

## 2. THE BEST TIME TO LEARN TECHNIQUE



Between the ages of 6-14 years, a period of rapid physical development, a child will spend more and more time performing the complex motor tasks that allow them to participate in sport (running, jumping, throwing etc). It is during this time that many
technical faults may arise, leading to inefficiencies that cause performance problems later on in the individual's sporting career.

The ability to greatly improve running speed and technique does not develop until most children are at least 6-7 years of age. It is at this age that we find the important strength component for running reaches a level where the child now accomplishes the basic running motor patterns for increased speed. It is also during these years that the nervous system is in a stage of rapid transition and learning takes place quite quickly. It should be during these formative years that basic running technique is addressed. Whilst untrained individuals will continually refine their running position, it is not uncommon to observe inefficient characteristics of running technique in adults (especially toe-out foot positions, lateral leg movements, excessive shoulder rotation and limited stride length).

Most people are able to jog using a natural style that is reasonably efficient, but to run fast requires the subject to adopt body positions that are not natural - some work is needed to integrate these movements into well-formed motor patterns. It is during the formative years of a child that these basic patterns (hip, knee, ankle, arm position etc) are ingrained. It is well understood by coach and movement experts that it is easier to develop a new motor pattern than it is to try to remodel an old, inefficient and incorrect motor pattern which was learnt at an earlier time.

The moral to the story is:

## DON'T TEACH BAD TECHNIQUE IN THE FIRST PLACE

## 3. THE BENEFITS OF SPEED TRAINING

Looking at junior sports performance, we find in many cases that the fast athlete is often the athlete who performs best. The attribute of speed is usually left up to the child's natural physical development but hopefully you can now see that it is possible to improve this skill at an early age. This will result in a better performance capability
regardless of the level of sport-specific skill of a junior athlete - obviously speed will not overcome a total lack of specific skill but it can make up for small deficits.

If a coach addresses all of the conditioning principles that are applicable to children and speed development, the result will be that the children can also improve other motor abilities such as coordination, agility, mobility and proprioception, all of which are important in the development of the young athlete.

Whilst I stated earlier that strength improves speed, it is also known that speed training improves strength and power. A contentious issue in coaching is the development of strength in pre-adolescent children (under 12-14 years). Concerns have been expressed that strength training that is too strenuous will have a negative impact on the child's growth, resulting in stunted limb length as they develop into adulthood. Performing bodyweight exercises can alleviate this problem. (See Chapter

## 14 for more information on this topic)

If a young child performs sprint training from an early age, there will subsequently be the development of:

- correct sprint technique;
- correct muscle-fibre types for explosive dynamic sports; and
- strength and power capacities at an early age.

All of these characteristics are important physical components for continued success in many sports.

An example of pre-adolescent strength and power training is the typical gymnastics training regime undertaken by athletes while they are still years away from puberty. Injury rates with these athletes are low but the development of their muscular and skeletal systems take place at a high level. If we take the most relevant components from such a program, it could be modified to address the more important components needed in sport, such as running speed, jumping and throwing technique.

## 4. THE TRAINING PROGRAM

It has been well documented that skill is the most important determinant of success in many sports, especially open sports requiring decision-making and the use of some external implement such as a ball, racket, bat etc. Also, most coaches only see their young athletes one or two times a week, so it is important that any coach wishing to integrate any of the aforementioned conditioning ideas into a training program does not neglect the young athlete's sport-specific skill development. The concluding section of this chapter presents an array of conditioning skills and drills that can be used to improve a young athlete's speed, strength and power levels.

## Training Drills

The following sample program has an emphasis on skill training, and is divided into three parts:

1. Warm-up ( 10 min maximum). Include total body exercises, such as squats, lunges, push-ups, sit-ups (any variations), running, and jumping (any variation).
2. Main routines ( $30-40 \mathrm{~min}$ ). Skills should be the main focus. Where possible, add elements such as sprinting, bounding and explosive throwing to the routines. Perhaps finish with a running/bodyweight circuit to emphasise fitness and continued strength training.
3. Cool-down (5-10min). This is the time to add static stretching to the routine to help maintain and improve the athlete's range of motion.

This sample program (and all of its variations) will help the young athlete to not only improve the all-important skill component of their sport, but it will also assist in the physical development that is equally important once high skill levels are attained.

All of the preceding exercises can be integrated into a training program using different components in different sessions to ensure that the young athletes maintain their enthusiasm. I believe that the warm-up (see Chapter 6 for more information on this topic) is the ideal time to encourage a young athlete's physical development. It is very efficient to incorporate many of these conditioning drills into a $15-20 \mathrm{~min}$ warmup routine and to cut down on the traditional jog-and-stretch approach, which is an inefficient use of both the coach and the athlete's time.

## Coaching Implications

1. You may want a child to develop their ability only in a particular sport, but you must understand that it is rare for a young child to remain in the same sport for the rest of their life. Therefore, look to give that child all the skills that will allow them to be successful in whatever sporting endeavour they decide to undertake later in life.
2. The least important attribute to train in a young child is aerobic fitness. Too much time spent on developing the aerobic system will decrease the development rate of the other physical attributes, such as balance and speed.
3. Speed, balance, coordination and strength should be incorporated into a young child's training and playtime to more quickly develop the skills they will need for success later in their sporting life.
4. Training (in the form of games) can be introduced to a child as young as 3-4 years of age.
5. Bone density in adults is best formed during their child-development years (5-15 years of age).
6. The most rapid learning of new motor skills by a child occurs between the ages of 6-14 years. It is during this time that a child should be exposed to as many different skills as possible.
7. Teaching "current technique" to a child early in their life will limit the potential frustration endured by this person later in their athletic career.
8. As soon as the young athlete can handle a particular skill, that skill should be modified to increase the level of difficulty and therefore continue skill adaptation.
9. For successful child training, the coach must have a large array of drills and skills to keep the children interested whilst challenging their neuromuscular system.
10. The long-term health and fitness of adults is directly related to their physical activity levels during adolescence.

## Chapter 17: <br> SPEED DEVELOPMENT FOR TEAM-SPORT ATHLETES



A sprint performance is made up of several components of which the first, the acceleration phase, is the topic of this chapter. Athletes require $25-50 \mathrm{~m}$ to reach their maximal running velocity, therefore the majority of sprint performances in team sports are acceleration runs. Very rarely will a team-sport athlete be required to sprint for longer than $30-40 \mathrm{~m}$ (even though an athlete in a football code may run up to 90 m if they make a break). Time-motion analysis of rugby union players highlighted the fact that centres sprinted at maximal effort for an average of 2.3 seconds $(15-20 \mathrm{~m})$ for each sprint. A similar study on netball centres found that they sprinted on average less than 1.5 seconds ( $5-8 \mathrm{~m}$ ) for each sprint. It is therefore important that coaches of sports teams place the emphasis of their sprint training upon rapid acceleration rates and the maximisation of the athlete's agility at speed.

## 1. DEVELOPING STRENGTH FOR SPEED

Speed-strength characteristics can be developed in the weight room but the best adaptations occur in a sport-specific, on-field situation. The training methods that can be used to maximise the rate of force development include sprinting with a weighted vest, uphill sprints, sled towing (see Chapter 10 for more information on these
topics) and speed-strength jump training (see Chapter 13 for more information on this topic).

## 2. TECHNIQUES TO MAXIMISE ACCELERATION



Development of the above strength characteristics will not ensure increased sprint performances in team-sport athletes if these physical abilities are not channelled into an efficient and functional sprinting technique. From my experiences in working with team-sport athletes over the past 10 years, lack of speed development is largely due to a poor sprinting technique that does not allow utilisation of the strength that an athlete possesses.

To maximise horizontal velocity, the athlete must be able to apply forces in a linear direction, minimise ground-contact time whilst maximising force output, maintain a correct mid-torso position, minimise rotation in the upper body during sprinting, and maximise the hip-extension forces created by the hamstring and gluteal muscle groups. A common problem that occurs when athletes attempt to sprint is the inefficient lateral movement of the lower limb through the phases of the stride, especially just after toe-off (push-off) and during early recovery of the foot to just beneath the gluteal. This lateral movement must be accommodated and usually results in excessive hip-rotation to offset the forces from the lower limbs, leading to very inefficient technique and consequently slow acceleration rates.

Another technical limitation is evident when the centre of gravity drops with a concurrent leaning backwards of the upper torso and accentuates a high-knee movement, which is an inefficient sprint technique. This position makes it impossible
to apply hip-extension force through a full range of motion, leading to a shortening of the stride and slower rates of acceleration. A good balance between knee-lift and leg extension is important for successful speed performances. (See Chapter 3 for more information on this topic)

Posture, and in particular the ability to hold a solid mid-torso position whilst sprinting, is one of the most important technical points in the development of sprinting speed. When developing speed in athletes, a large amount of training time should be spent on drills that emphasise a solid mid-torso. The more solid this region, the better the upper and lower limbs are able to perform their functions without upsetting the direction of force production and the ultimate goal of improving the rate at which the ground can be covered. When observing elite sprint performers, it becomes clear that many of these athletes sprint with elbow angles at much greater than the suggested $90^{\circ}$, and that they can only effectively use this technique by developing great strength throughout their mid-torso region (see Chapter 8 for more information on this topic). A long lever (length of limb) will develop more force than a short lever if the associating structures are strong enough to withstand the increase in force development. The technical faults described above have the effect of increasing braking forces as the foot makes contact with the ground in front of the centre of gravity. This in turn increases ground-contact time and decreases flight time, resulting in decreased acceleration ability.

## 3. DRILLS TO IMPROVE ACCELERATION, BODY POSITION \& AGILITY



Sprint drills can be divided into two categories: sprint-specific drills, which are aimed at improving body posture and sprint technique, and sport-specific drills, which focus on the maximal adaptation of speed to the specifics of the game in question.

## Sprint-Specific Drills

As has been detailed earlier in this book, sprint-specific drills are designed to improve body posture, hip position, and leg and arm action, also the rate of hip-extension and the speed of limb recovery after toe-off. (See Chapter 12 for more information on this topic)

## Sport-Specific Drills

To make speed drills specific to certain team-sport movements, lateral movements and a reaction-time component can be added to them. This means drills should include jumping, sprinting (forwards, backwards or sideways) and/or stepping (forwards, backwards or sideways) rapidly on a signal that can be auditory (clap), visual (flag, throwing of ball, waving of hands etc), or kinaesthetic (touching the athlete on the back of the head, the legs, the back etc). The drills could include the athlete having to dive to the ground and get back up quickly (as required in volleyball), or to take a couple of steps forwards and then backwards to a jump (as in netball).

Another drill of benefit to team-sport training requires the athlete to quickly get off the ground and sprint to a particular point either forwards, backwards, sideways, or via a combination of these. The position on the ground should be varied and include lying face down, the push-up position, lying on the back, sitting, and having arms and legs in different positions. This can be modified further to have the athlete pick up a ball on their way from the start position and sprint through whatever obstacles are appropriate. This type of work increases the athlete's proprioception and their ability to quickly move into a sprint position and cover ground rapidly.

Potential combinations of starting and reaction drills are limited only by a coach's imagination. However, of utmost importance is that the speed and reaction drills are performed at maximal intensity and whilst the athlete is fresh (at the beginning of any session). It is also important that long recoveries are allowed between drills to ensure that the athlete maintains quality speed of movement - 1min between a set of reaction drills (3-5 repetitions of the drill, or approximately 10 sec of work) and $1-2 \mathrm{~min}$ between 40 m sprints. As most sprint training is aimed at developing the neuromuscular system, the nervous system of the athlete must be in a non-fatigued state to allow improvement to occur. As soon as the athlete's nervous system becomes fatigued, no further improvement takes place. The athlete then adapts to performing speed movements under fatigue which, whilst required in a game situation (such adaptation can be done during the competition phase of training to simulate the sports-specific fatigue that may occur during a game situation), doesn't lead to speed improvement, merely to the same speed under fatigued conditions.

## 4. DEVELOPMENT OF SPEED ENDURANCE

In the development of speed-specific endurance, as in the development of increased acceleration speed, the distance to be covered in performance is important in determining the structure of the training session. A team-sport athlete will rarely have to sprint more than 40 m in any single effort, so training at distances much greater than 40 m is of little relevance to speed or speed-endurance development in team-sport athletes. There are football codes that still require their athletes to sprint up to 400 m and run fast up to 800 m during training. There is no rationale for this type of training in the development of speed endurance (unless there is a need to inflict great pain on
the athletes involved!). During sprinting, once the athlete goes beyond 40-50m they are at top speed and are therefore developing sprint characteristics irrelevant to a game situation. To be asked to run $400-800 \mathrm{~m}$ leads very quickly to athletes tackling these distances at much less than the $90-100 \%$ intensity that is demanded in a game situation.

Speed-endurance training can be performed over distances of 5-50m (depending upon the sport). But it would be more appropriate if athletes performed a series of repeat sprints over short distances (see Figure 17a). For example, 4-5x30m back-to-back drills performed at $100 \%$ intensity are specific to all football codes and hockey, whilst for netball, a session such as $3 \mathrm{~m}-3 \mathrm{~m}-6 \mathrm{~m}-6 \mathrm{~m}-9 \mathrm{~m}-9 \mathrm{~m}$ continuous sprinting (forwards and backwards) is more specific than performing 100 m repetitions. Another advantage of developing speed endurance over short, repeat distances is that the coach can be close to the athletes, enabling them to give encouragement or feedback on technique as the players begin to fatigue.

```
Field team-sport athlete (football codes, hockey etc)
4x30m walk back
3x40m walk back
2x60m walk back
5x10m jog back
5x15m jog back
Court team-sport athlete (netball, basketball etc)
5x2.5m jog back
5x5m jog back
4x7.5m jog back
3x10m walk back
Shuttle run 1x5m, 5m, 10m, 10m, 15m, 15m; rest 60-90sec; repeat
```

Figure 17a. Examples of speed-endurance sessions
Any combination of distance, recovery, speed of the sprint, and the number of repetitions and sets is appropriate, and is dependent on the fitness level of the athlete.

## 5. PERIODISATION OF SPEED TRAINING

The development of speed, like the development of strength, should be planned to take place throughout the total training year. It is unrealistic to have athletes perform high volumes of endurance and strength work in the preparation phase (off-season) and to then begin speed work in the competition phase, and expect them to achieve great gains in sprinting speed.

Endurance training has an adverse effect upon strength and speed of movement. Athletes who perform large volumes of endurance training in the preparation phase to develop basic endurance capabilities (with little to no speed-development training) will decrease their speed potential, making speed gains difficult to achieve.

To ensure maximum conversion of strength to sprinting speed, it is recommended that athletes perform sprint training year-round. In the preparation phase this can take the form of technique runs and, to improve basic speed-endurance capabilities, athletes can perform repeat runs over $10-50 \mathrm{~m}$ intervals (sport-dependent) with short recoveries $(90-120 \mathrm{sec})$. The negative effect of endurance training on speed can be minimised if the athlete is performing sprint training during an endurance phase of training. This will ensure that the correct neural pathways are being stimulated and that the fast-twitch muscle fibres are being challenged. To maximise all of the characteristics required by the team-sport athlete, it is important to periodise the training year so that there will be speed, strength, endurance or power development occurring throughout each phase of training. (See Chapter 15 for more information on this topic)

## Sample Training Week

Following is an example of a development (strength and speed) and maintenance (aerobic conditioning) training week:

Monday Weights/speed
Tuesday Skill session (minor aerobic component at end)
Wednesday Weights/speed
Thursday Rest
Friday Weights/speed

| Saturday | Aerobic conditioning |
| :--- | :--- |
| Sunday | Rest |

The best adaptation occurs through 2-4 sessions of the one component per week (e.g. weights) and maintenance can be achieved with 1-2 sessions per week (aerobic conditioning)

For younger athletes who only train once or twice a week, a particular training week should be structured so that skill is the main focus, while both endurance and strength (for example) could be addressed during each session. Even though there may be a training conflict between these two physical components with younger athletes, high levels of either attribute are not required so mutual development should not cause any training problems.

## Coaching Implications

1. The development of high strength levels in the weight room is only the first step for an athlete - this strength must still be adapted to a sport-specific, on-field situation.
2. The most important consideration for a team-sport athlete is not perfect technique, but a functional, stable, injury-limiting sprint technique.
3. The development of explosive strength should be the main focus of the sprint program for team-sport athletes. This aim can be achieved through the use of several resisted speed methods and varied acceleration runs from a variety of starting positions.
4. The development of great strength in the mid-torso region is a precursor to correct posture and therefore to greater running speed.
5. Once linear speed technique has been developed, then sport-specific speed development is required (movements being lateral, backwards, sideways, sidestepping, swerving etc). If the athlete bypasses the linear speed technique phase they are often limited later on by poor sprint mechanics.
6. Don't ask team-sport athletes to maximally sprint more than 40-50m. This type of training does not follow the training principle of specificity.
7. Once the required speed level has been reached, repeated speed runs (of high quality) will develop sport-specific speed endurance.
8. Speed work needs to be integrated into the training program year-round.
9. More technique and power training is needed in the pre-season and more specific speed training during the competition phase.
10. Both strength and endurance should be incorporated early on in a young athlete's training regime, although the main focus of training must be on skill development.

## APPENDIX 1:

## TESTS \& PROTOCOLS - SPEED, AGILITY, POWER \& ENDURANCE

## 1. 5-60M SPEED TESTS

Equipment required:

- Timing lights (DDH, KMS etc) or stop-watch
- Cones
- Measuring tape or measure wheel



## Protocol

If timing lights are available.
The athlete is asked to line up at a set distance from the initial timing light - any distance up to 30 cm . When the athlete is ready, they attempt to run through all the gates as fast as possible. It is important that you place a cone $2-5 \mathrm{~m}$ past the last gate and instruct the athlete to sprint all the way to this cone. This will stop them from slowing down as they approach the last gate.

Note that it's possible when using timing lights to test several distances at once.

If only a stop-watch is available.
You will only be able to test one distance at a time and the best protocol is to start the watch as soon as the athlete's trailing foot leaves the ground. The athlete has finished the run when their torso passes across the line.

## 2. 5-0-5 AGILITY TEST

## Equipment required:

- Timing lights (DDH, KMS etc)
- Cones

- Measuring tape or measure wheel


## Protocol

The athlete lines up 10 m from the timing lights and, when ready, runs towards the lights and to the line 5 m beyond the gate. The objective of this test is for the athlete to touch the line with one foot (each foot must be done for comparison) then turn and run back the way they came. The timing lights measure how long it took for the athlete to travel 5 m , turn around, and sprint back 5 m .

This test is quite basic but has been highly correlated with more sport-specific agility test protocols. This makes it a very good test because it's simple, you can measure the efficiency of the athlete off either foot, and it relates highly to other agility measures.

## 3. STANDING LONG JUMP

Equipment required:

- Cones
- Measuring tape or measure wheel
- Sand-pit



## Protocol

The athlete starts with the toes of both feet on one line and, when instructed, attempts to jump as far as they can into the sand-pit. The distance achieved is measured using the foot that lands closest to the take-off point. The athlete is allowed to have a double-arm swing.

## 4. VERTICAL JUMP

Equipment required:

- Measuring board, or jump mat and computer



## Protocol

From a standing position, the athlete jumps and attempts to touch the measuring board as high up as they can. The difference between the standing height and the jump height is then measured.


With the use of the jump mat, the athlete performs a vertical jump similar to the one described above. But as the mat determines jump height (time in the air is converted to vertical distance achieved) it is possible to have the athletes do the jump whilst holding their hands on their hips - it has been determined that an athlete can achieve an increase of 10 cm with the use of their arms.

## 5. GLYCOLYTIC TEST 1

Equipment required:

- Cones
- Measuring tape or measure wheel
- Stop-watch


## Protocol

The athlete is required to run a 35 m distance and this is timed to within a hundredth of a second. The athlete is given 30 seconds recovery and is then asked to repeat the 35 m run. This is to be done eight times and the decrement in time of the sum of the last two runs compared to the sum of the first two runs is converted into a percentage decrease in performance. So as an equation, A (Run $7+$ Run 8$) / B(R u n 1+\operatorname{Run} 2) x$ $C(100)=E$ (percentage decrease in performance). This is believed to be a good measure of an athlete's anaerobic fitness.

The closer the result is to 100 , the better the athlete's anaerobic endurance.

## 6. GLYCOLYTIC TEST 2

Equipment required:

- Cones
- Measuring tape or measure wheel
- Stop-watch



## Protocol

This test involves adding agility (change of direction) to the measure of an athlete's anaerobic endurance. The athlete is required to complete the course, have a break of 30 sec , and then repeat the process eight times. Again, the difference between the first and last two runs is compared to get a measure of the athlete's ability to sustain high anaerobic energy activities.

## Recommended Resources

$\underline{\text { Training Kids for Speed }}$


Paul Cheks Swiss Ball Video 'Better abs,buns \& backs"


My squad do this Swiss ball workout 2-3 times a week for most of the year.
Paul Check's Swiss Ball Exercises for Athletes Vol 1 - VHS


Excellent Training Video Series that shows how to train using a Swiss Ball for best effects.


Excellent Training Video Series that shows a full Swiss Ball workout that is performed using the right methods.

Denise Austin - Mat Workout Based on J.H. Pilates (2000)


This video contains $2 \times 20$ minute workouts - They are great to incorporate with other workouts or use alone when time is limited. Workout 1 is all pilates. Workout 2 combines yoga and pilates. My squad does this 2-3 times a week.

How to strengthen the lower parts of your legs, and prevent (or repair) shin-splint problems.
by O. Anderson and W. Reynolds http://www.pponline.co.uk/encyc/0161.htm

Back to Basics
by Vern Gambetta
To do with development of children and physical activity http://www.gambetta.com/a97001p.htm|

Functional Balance
by Gary Gray and Vern Gambetta
Ideas to do with balance training
http://www.gambetta.com/a97002p.html
Too Loose Too Much
by Vern Gambetta
The truth about stretching
http://www.gambetta.com/a97003p.html
Following the Functional Path
by Vern Gambetta and Gary Gray, PT
Functional training explained
http://www.gambetta.com/a97004p.htm
Leg Strength for Sport Performance
by Vern Gambetta

The functional way to strength train legs
http://www.gambetta.com/a97006p.html

## Learning to Move

by Vern Gambetta
http://www.gambetta.com/a97007p.html

## Plyometrics: Myths and Misconceptions

by Vern Gambetta
http://www.gambetta.com/a97008p.html

Neuromuscular adaptations following prepubescent strength training.
Ozmun, J. C., Mikesky, A. E., \& Surburg, P. R. (1994).
http://www-rohan.sdsu.edu/dept/coachsci/vol66/ozmun.htm
Strength Training for Children
by J. Graham
http://www.faccioni.com/Reviews/childstrength.htm
The Use of Medicine Balls for Speed \& Power Development
by A. Faccioni
http://www.faccioni.com/Reviews/medballtraining.htm
The Role of the Mid-Torso in Speed Development
by A. Faccioni
http://www.faccioni.com/Reviews/midtorsospeed.htm
Plyometrics
by A. Faccioni
http://www.faccioni.com/Reviews/plyometrics.htm

## Dynamic Warmup Routines for Sports

by A. Faccioni
http://www.faccioni.com/Reviews/Warmup.htm

## Speed Training for Team Sport Athletes

by A. Faccioni
A range of good ideas
http://www.faccioni.com/Reviews/teamspeed.htm
Pilates ReTraining of Lumbar Stabilisation Muscles
Some explanation of value of Pilates exercises
http://www.faccioni.com/Reviews/pilates.htm
USA Sprint Tech Info.
by Adrian Faccioni
(Power Point Presentation)
486Kb zip file
Brilliant description and analysis of modern sprint biomechanics and training. http://www.faccioni.com/articles/USA\ Speed\ Presentation\ 2000.zip

The Inner Unit - A new frontier in Abdominal Training
by Paul Chek

Great article
http://www.coachr.org/innerunit.htm

## The Outer Unit

by Paul Chek
Great article outlining importance of specialized core conditioning
http://www.coachr.org/outer.htm

The Use Of Swiss Balls In Athletic Training-
An Effective Combination Of Load And Fun
By Klaus Bartonietz, Germany, and Debbie Strange, New Zealand
Some explanation of value of Swiss Balls
http://www.coachr.org/sb.htm

Young Athlete Conditioning
by Adrian Faccioni and Di Barnes
Excellent article
http://www.faccioni.com/lectures/juniorcondition.PDF

## 'Run-Play' Training

Some Creative training ideas
http://www.pponline.co.uk/encyc/0272.htm

Proceedings of the Conference on Strength Training \& the Prepubescent Information about safety of strength training for kids http://www.sportsmed.org/Publications/..\%5Cpdf\%5Cstrength training prepubescent.pdf

Why sprinters should cock their ankles
Explanation of Dorsiflexion
http://www.pedigest.com/sample/biomechanics.html

The Simple Secrets of Developing Great High School Sprinters by Bryan E. Hoddle
Some useful ideas and explanation
http://www.watfxc.com/TF/TF\ Education/Hoddle1.htm

## Training for Speed by Charlie Francis



A recommended book on Sprinting. Contains plenty of great sprint training ideas. Written by the coach of Ben Johnson who ran 9.79 for 100 m in the Seoul Olympics. For more information

Speed Agility and Quickness
by Brown, Ferrigno and Santana


Heaps of ideas for activities that develop Speed, Agility and quickness.

Training for Speed and Endurance
by Peter Reaburn (Editor), David Jenkins (Contributor)


The contributors to Training for Speed and Endurance are sports specialists keen to bridge the gap between laboratory findings and athlete preparation. They are all involved in the training and preparation of elite athletes, and their aim in writing this book has been to provide practical guidelines for developing and maintaining speed and endurance fitness for both individuals and team players. Training for Speed and Endurance will make sense of all the new techniques and the latest research. It will be of interest to anyone wishing to gain up-to-date information on training principles and will be of particular value to those individuals or team players who need to focus on speed and endurance. The book is an excellent resource for coaches, individual athletes, health and physical educators of senior students, and tertiary students of sports science.

Sprints \& Relays: Contemporary Theory, Technique and Training by Jess Jarver


Great compilation of recent research to do with Sprints \& Relays.

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