FITNESS TRAINING

The following training drills are included in this section:

The sport of tennis involves many aspects of performance, including strength, power, speed, coordination, agility, flexibility, and endurance. Training to maximise performance in all these areas simultaneously is a difficult task.

These principles of training provide guidelines the player can follow to increase the chances of receiving maximum benefit from training. Violation of these principles may lead to overtraining, overuse injuries, or simply the failure to reach optimal levels of performance.

Adaptation

Adaptation is the process the body goes through to improve the functioning of a specific system in the body in order to meet the demands placed on it. The principle of adaptation states that the body will adapt to stresses that are appropriately applied.

Running long distances causes adaptations to occur to the heart, lungs and lower body musculature to improve running performance. Similarly, in tennis when a player practices a serving, the muscles used in the serve are adapting to improve their ability to perform that specific task.

Loading

Training at too heavy loads may impair performance and lead to overtraining or lead to overuse injuries. In order to improve VO2 max, the athlete should exercise at a level that challenges their ability to consume oxygen. To build strength, the athlete should be challenged to lift loads heavier than the loads they lift in daily activities.

To maximise athletic performance the body should be "loaded" at a frequency, intensity or duration higher than the level to which it is accustomed.

The difficult part is trying to design a training programme that does overload the athlete's body without causing overtraining or overuse injuries. Therefore, it is important to accurately assess the workloads that produce maximum performance without increasing the risk of injury.

Specificity

The principle of specificity states that the adaptations that occur to the human body when exposed to exercise stress are specific to the type of applied stress. One should consider specificity within a variety of physiological parameters. What is specific for one player may not be a specific for another.

Just as a midfielder and a goalkeeper train differently in soccer, so should a serve-and-volleyer and baseliner train differently in tennis. Specificity of training essentially means that the training should be both metabolically and mechanically specific to the demands of the sport of tennis.

The physiological demands are specific to the style of play, the level of play, the style of play of the opponent and the court surface.

Metabolic specificity includes the length and intensity of the work intervals, and the length of rest intervals. Based on the length of the points, particularly on fast surfaces, it would appear that tennis is primarily an anaerobic sport with the aerobic energy system involved in recovery between points.

With both the aerobic and anaerobic energy systems playing a role, the key is to train each system specific to the sport of tennis.

Mechanical specificity involves using the muscle specific to the way they are used on the tennis court. This can best be characterised as power endurance, as it consists of repeated bouts of power output over an extended period of time.

Each stroke involves a burst of power of the legs, trunk and upper extremity. Depending on the situation, some amount of sprinting/running is required of the lower extremity prior to and after each stroke.

Intensity

Intensity of training strongly relates to specificity. It is not the length of the points and rest intervals that is important, but the effort or intensity during that time.

The purpose of a training programme should be to improve performance at the intensities that are specific to the sport of tennis. Heart rate can be used to measure intensity.

The specificity principle would state that the heart rate profiles in training should be specific to the heart rate profiles in matchplay. Furthermore, since the rating of perceived exertion (RPE) is correlated to heart rate, a RPE can be potentially valuable in determining the intensity of tennis play.

Volume

Volume is the total amount of training, and should include on-court and off-court training.

Monitoring the volume of training along with the intensity is the best way to monitor total training workload and hopefully monitor overtraining.

The volume of training will be individualised to the extent that specific players have specific weaknesses they should work on. The volume of off-court training will be higher in the preparation phase, and gradually decrease as the competition phase approaches.

The volume of on-court training will begin relatively low in the preparation phase, and gradually increase as the competition phase approaches.

Frequency

The frequency of training can be the number of training session per day or per week. As with volume, the frequency of training should vary with the goals of the individual as well as the period of training.

Frequency of training depends on the desired outcomes of the type of training involved. For gains to occur in strength and power, a training frequency of 3-5 days per week is recommended, although highly trained athletes may be able to train at higher frequencies.

Variety

The principle of variety appears to conflict with specificity. The key is to select a variety of exercises within the limits of specificity. For example, within the realms of "anaerobic sprint training", a variety of footwork patterns can be prescribed.

By using a variety of exercises or drills, sessions are made more enjoyable and players are less likely to become bored. They are more likely to be more motivated and improve their performance in the given area they are training.

Recovery

The principle of recovery states that the player should allow time for recovery in order to continue to improve. Without the appropriate recovery time, the player will not adapt to the stress of training, and will possibly experience overtraining or overuse injuries. With too much time for recovery, the player will not adapt at an optimal pace and therefore is unlikely to reach maximum performance.

FLEXIBILITY TRAINING

Flexibility, like strength or endurance, is a functional component of movement and typically refers to the range of movement (ROM) around a joint.

The development of flexibility is most commonly sought through a variety of stretching techniques. The most commonly used forms of stretching are:

- Static stretching
- Dynamic Stretching
- Proprioceptive neuromuscular facilitation (PNF)

For many years, stretching has been proposed as a way to increase flexibility, decrease risk of injury, prevent muscle soreness, and improve performance. All of these techniques have their own protocols and are most effectively performed at certain times.

Contrary to popular belief, pre -exercise stretching does not prevent injury, and static stretching done in the period 30-45 minutes prior to activity leads to substantial decreases (5-30%) in muscular performance. It is important for players to understand how, when and to what extent these forms of stretching should be carried out.

Static Stretching

The static stretching exercises are the most widely used stretches in tennis. The muscle is slowly and gently stretched to the point of slight muscle discomfort and then held for 15-30 seconds. While the position is maintained, the acuity of muscle tension decreases and the athlete should increase the amplitude of the stretch.

Static stretching is effective in increasing the ROM of different joints and the flexibility of the target muscle.

Players should endeavour to perform a static stretching routine twice a day, with good times for athletes to perform static stretching being post exercise and/or in the evenings. The fact that static stretches can be performed anywhere without any form of assistance from trainers or equipment is advantageous.

Although static stretching can increase passive flexibility, there is no research to demonstrate its correlation with the dynamic flexibility required for the sport of tennis. In addition, static stretching within an hour before exercise does not reduce the risk of injury, and impairs performance in speed, power and strength activities.

The deficit in performance lasts approximately 60 minutes after the stretching routine, and may be due to changes in reflex sensitivity, muscle/tendon stiffness and/or neuromuscular activation.

Dynamic Stretching

Dynamic stretching involves moving parts of your body and gradually increasing reach, speed of movement, or both. Dynamic stretching is not to be confused with ballistic stretching.

Dynamic stretching consists of controlled leg and arm swings that take you (gently) to the limits of your range of motion.

Ballistic stretches involve trying to force a part of the body beyond its range of motion. In dynamic stretches, there are no bounces or "jerky" movements. An example of dynamic stretching would be slow, controlled leg swings, arm swings, or torso twists.

Dynamic stretching improves dynamic flexibility and is useful as one of the final components of a sport-specific warm-up. The primary benefits of dynamic stretching include increasing body and muscle temperature and intramuscular blood flow, as well as their application in readying the specific musculature involved in the game of tennis.

Generally, dynamic exercises are performed in sets of 8 to 12 repetitions. After reaching the maximal range of motion in a joint in any direction of movement, you should not do many more repetitions of this movement in a given workout.

Proprioceptive neuromuscular facilitation (PNF)

The techniques of Herman Kabat, the originator of PNF in the 1950's, combine isometric, concentric and eccentric contractions with passive movements.

PNF is typically applied manually with the assistance of a trainer, however players may also perform it individually. The neurophysiological basis of facilitated exercises are summarised below:

Muscle Contractions

Two types of muscle contractions are used in PNF: Isotonic and Isometric. Isotonic muscle contractions are voluntary muscle contractions that create movement. This type of contraction can be further classified as either concentric, where muscles shorten as they work, or eccentric in which muscles help control or offer resistance to movement as they elongate. Isometric contractions are voluntary contractions in which no movement is produced and the muscle length remains the same.

Stretch Reflex

The muscle or myotatic stretch reflex prevents muscles from stretching too quickly or too far and thus is a protective mechanism against joint and/or muscle injury. However, as alluded to in the section on ballistic stretching, the evoking of the stretch reflex causes the stretched muscle to contract and for this reason its elicitation should be avoided when perfoming a stretch. The administration or performance of PNF stretches that are smooth and prolonged is consequently very important.

Inverse Stretch Reflex

The inverse stretch reflex is the second reflex that coaches and trainers should be mindful of when performing PNF stretches. As its name suggests, it produces the opposite effect to that of the abovementioned stretch reflex: when evoked, the stretched muscles relax. There are two ways of stimulating this reflex. First by performing a smooth and maintained isometric stretch that triggers localised muscle relaxation and an increase in range, or secondly through the use of post-isometric relaxation as follows: after an isometric contraction there is a refractory period of about 15 seconds in which it is easier (because of a decrease in muscle tone) to increase the ROM (establish a new resistance limit) of a joint or muscle.

Advantages of PNF

There have been scientific studies that have purported PNF techniques to improve flexibility more so than any other stretching technique (Moore and Hutton, 1980). The performance of isometric muscle contractions as part of the PNF technique has also been suggested to help improve muscular strength and thus be of additional benefit from an injury prevention perspective (Moore, 1979).

The role of PNF stretches in relaxing and providing improved circulation to the stretched muscle is similarly considered beneficial (Adler et al., 1993; Cherry, 1980).

Disadvantages of PNF

Players should be motivated and focused if they are to practice these techniques safely and effectively. To “get up” for stretching sessions can often be difficult for the professional player and thus the role of the trainer or coach in encouraging and motivating the player can be important here.

The need to have a coach or trainer to assist with the performance of the majority of the PNF stretches can in itself be considered disadvantageous. Likewise, that PNF stretching exercises are more complex and intense than other stretching methods may contribute to their lack of popularity among some players.

Techniques

PNF uses a variety of techniques that incorporate isometric and isotonic contractions to varying degrees in order to obtain specific results. Among all the PNF techniques, ATP Trainers only use the contraction-relaxation technique (Basthold and Novotny, 2002). Contraction-relaxation is considered by the author to be the most beneficial technique for tennis performance.

This method requires that the trainer move the desired segment in a passive manner until end range is reached. At this point the player contracts the stretched musculature isometrically against a resistance provided by the trainer (5 to 10 seconds).

The player will then relax (10 to 15 seconds) before the trainer moves the segment to a “new” end range (i.e. beyond the end range reached when the trainer first passively moved the segment) where the player will again perform an isometric contraction against the resistance provided by the trainer (15 seconds).

This process is repeated three or four times with an increase in the joint’s ROM being achieved with each repetition.

SPEED & AGILITY TRAINING

A tennis player must be able to respond to different sorts of signals, move quickly, with constant changes in direction in order to become a successful athlete. Therefore, it makes perfect sense to combine speed and agility training.

The combined approach to the development of speed and agility should provide players with the opportunity to take part in training situations, which are more fulfilling, more original and more fun. Furthermore, combined training will enhance tennis-specific movements, and therefore performance.

Although the speed and agility components of fitness are combined when training, it is still important to consider the individual components and the practical applications of both speed and agility for the sport of tennis.

SPEED

Speed can be defined as "the ability to complete a movement within a short period of time". Therefore, to improve speed, players must develop the ability to accelerate and slow down. To enhance these abilities, players and coaches must take three components into consideration:

- Reaction speed – the ability to respond quickly to different types of signals.
- Contraction speed of the muscles - the ability of the muscles to make explosive movements.
- Frequency of body movements - the ability to execute body movements correctly at different speeds.

In which situations does the player need these qualities to succeed?

- When a player tries to make quick first steps.
- When a player performs movement patterns and changes of direction at high speed.
- When a player decelerates over a few steps to set themselves optimally to make ball contact.
- When a player hits powerful shots on the serve and from the baseline

AGILITY

Agility is a quality that is often thought to be at a premium among "talented" players. The impression of ease with which they play is such that some observers think that they were "born with a racket in their hands".

Agility can be defined as the ability to change the body's direction efficiently. This means being able to execute the movement smoothly with accuracy and relaxation, thus using minimal muscular energy.

To enhance these abilities, players and coaches must take the following components into consideration:

- Movement coordination – provides for success in more complex situations.
- Movement precision – the quality of execution.
- Energy saving – the ability to execute a motor activity with maximal efficiency.
- Reliability of motor execution – the ability to reproduce the performance with a high level of success.

In what situations do tennis players demonstrate agility?

- When playing the right shot with efficiency (i.e. high backhand volley played with a lot of ‘touch’, strokes executed with good ‘timing’).
- When adapting to specific game conditions (i.e. adjusting to a difficult shot with no apparent effort).

COMBINED TRAINING EXERCISES

EXERCISE 1: Ball Drops

Purpose

To develop the reaction speed of the player, their starting ability and their agility

Set-up

1. On a tennis court or playing area, the coach/assistant stands in front of the player and drops a ball.
2. The player has to catch it before the second bounce.

Equipment

- Tennis balls

Interventions

On the attitude of the player in the ready position:

- Legs slightly bent, the player stands on the balls of the feet.
- The player should be ready to act and be focused on the ball.

At the start:

- Keep the trunk straight during the beginning of the action.
- Use the arms in the direction of the movement.

On the catching of the ball:

- Maintain dynamic balance.
- Increase the number of steps to slow down.
- Modify the Situation

To make it easier:

- Get closer to the player.
- Feed only one ball.
- Increase the height of the drops.

To make it more difficult:

- The coach/assistant should vary their positioning with reference to the player
- Change the starting positions
- Feed more than one ball
- Drop two balls successively

EXERCISE 2: Fan Drill

Purpose

- To develop the starting ability of the player and their ability to change directions.
- To improve the action of the foot on the ground.

Set-up

1. On a tennis court, player starts behind a racket placed on the baseline 'T'
2. The player runs to ball 1, picks it up, runs back to the 'T' and places the ball on the racket
3. The player then runs to ball, picks it up, and returns it to the racket
4. This process is repeated for balls 3, 4 & 5.
5. The drill is completed when all 5 balls are placed on the head of the racket.

Equipment

- 5 tennis balls
- Tennis racket

Interventions

On the attitude of the player when running:

- Insist on a strong arm action and use the arms in the direction of the movement.

When picking up/putting down the ball:

- Increase the number of steps to slow down.
- Maintain dynamic balance.
- Optimise knee bend.
- Plant outside like for optimum stability and propulsion.
- Be aggressive to the ground for optimum propulsion.

Modify the Situation

- Perform the exercise on a clay court to integrate sliding to the drill.

POWER TRAINING

Power is a quality that is associated with speed of movement. In tennis, the emphasis is on the "first step" and quick change-of-direction, early set-up, etc. All of these terms relate to the ability of the player to overcome the inertia of their own body/weight and to initiate movement. The faster athletes do these things the more impressive they are.

The tennis players who can apply their strength most effectively are the ones who can hit the ball hardest and serve the fastest. This is why power as well as strength is important. Using a system of training known as "plyometrics" best develops power.

Plyometrics

Plyometric drills are generally conducted as a form of "jump training". The method of training which seeks to enhance the explosive reaction of the individual through powerful muscular contractions as a result of rapid eccentric contractions.

Plyometric training for the lower extremities is often classified according to response of ground contact times. Thus, the terminology "rapid response" and "longer response" appears in the literature.

Rapid response exercises are generally used to develop footwork drills. They are performed as brief, quick responses to the ground contact. Plyometrics that use the total lower extremity in larger amplitude movements such as jumping or bounding are intended to develop a higher degree of force and thus require longer ground contact times in order to develop these forces, and are known as "long response" jumps.

The physiological basis of plyometrics lies in what is known as "stretch-shortening" cycle of muscle activity. Muscles are designed in such a way that when rapidly stretched, they 'rebound' and shorten in reaction to rapid stretching.

This only occurs when the magnitude and rate of stretch is rapid and of sufficient magnitude that it will trigger this muscle action. This rebound effect allows the muscles to develop more forceful and faster contraction speeds than if they are not subjected to a stretch stimulus.

Intensity of plyometric training

It is important to control the intensity of training by setting limits to the distance or height over which the player jumps. There is little need for vertical jumping ability in tennis, thus, most of the jumping drills will be focused on linear efforts over boxes and barriers that are not of great height. In tennis, hurdles and boxes used as barriers for training should rarely exceed 0.35-0.4m in overall height

The energy system most likely to be involved in tennis training using plyometrics will be the ATP-PCr system. This system requires exercise effort to be maximal and last (duration) from 1-15 seconds.

The utilisation of oxygen is too slow to meet the demands of this type of activity and the energy stores in the muscles (ATP and creatine phosphate) are utilised rapidly until they are exhausted and the muscles cannot function. Therefore, rest ratios should allow for energy replenishment and require much longer times than the work bouts. Work to rest ratios are generally considered to be 1:5 – 1:10.

If the exercise lasts longer than 15 seconds and up to 60 seconds, then anaerobic glycolysis may be utilised.

In this situation the cardiovascular system still cannot utilise oxygen adequately. Therefore, an oxygen debt is encountered and energy is derived from both the ATP-PCr system and anaerobic glycolysis.

Work:rest ratios in this form of training are also usually 1:2 – 1:6.

Volume of Plyometric Training

The number of "reps" and "sets" utilised in plyometric training for tennis will depend on the age of the player (see Table 1). Young athletes, inexperienced as weight trainers, benefit from motor learning and recovery. Therefore, they should do fewer drills and be taught to do them correctly. Even a simple task such as jumping to the top of a 0.3 m box requires some learning of body mechanics to correctly take-off and then land on an elevated surface.

Age	Number of Exercises	Sets	Repetitions
8-10	3	1	5-10
10-12	3-4	2	8-12
12-14	4-5	3	12-15
14-16	5-6	3	12-15
16-18	6-8	4	10-15
18+	8-10	4-5	10-20

Table 1. Recommended plyometric training programmes based on the age of the player.

The most successful plyometric drills in working with tennis players are those that are specifically related to the game itself. Plyometric exercises are centred on reducing ground contact time. In order to develop faster reactions to landing and getting off the ground a certain amount of learning should occur. It is advisable to allow players to perform a "warm-up" set of exercises at less than all-out effort prior to focusing on maximum efforts.

EXERCISE 1: Jump to Box

Purpose

To develop lower extremity power.

Performance

The player stands with their feet shoulder width apart (0.3-0.45 m) in front of a sturdy box, 0.3-0.6 m high. The player jumps vertically as high as they can and lands on the box. Both feet should be entirely on the box at landing. The player should then step off the box and repeat for the required number of repetitions.

Pointers

Control the landing; land softly! Finish with entire feet on the box.

EXERCISE 2: Split Squat Jump

Purpose

To improve hip flexibility and hip flexor power.

Performance

The player assumes a split squat position with one foot forward and the other projected to the rear. Hands can be placed on the hips. In this position the front knee will be bent at 90° and the rear knee will be almost touching the ground. The player will jump as high as possible and switch the position of the legs before landing.

Pointers

Focus on the landing and maintain the torso in an upright posture.

EXERCISE 3: Side-to-side Box Shuffle

Purpose
To improve the ability to push-off the ground in a lateral direction.

Performance
The player stands next to a sturdy box approximately 0.5m wide and 0.3m high. The player places their right foot on the box while the left foot remains on the ground. The player then pushes up and across the top of the box; landing with the let foot in the middle of the top of the box and the right foot on the ground. Continue to shuffle back and forth across the box for the prescribed number of repetitions.

Pointers
The player should use their arms to facilitate their lifting from the ground. Land softly and control the landing. Try to move back and forth in a smooth manner.

EXERCISE 4: Lateral Cone Hop

Purpose
To improve the player's reactivity to the ground.

Performance
Line up 5-6 cones (0.3-0.35 m high), spaced 0.6-0.9m apart. The player stands with their side at one end of the line of cones. The player then jumps sideways over the cones landing on both feet until they reach the last cone. At the last cone the player lands on a single foot (outside leg) and immediately pushes back repeating the exercise in the opposite direction.

Pointers
Smaller cones should be used when the player first performs the drill. The player should try and jump back and forth an odd number of times so that they have an equal number of single foot landings at the ends.

STRENGTH TRAINING

STABILISATION STRENGTH

Stabilisation strength refers to the muscles and systems that support each and every joint, as well as make up the core/pillar strength.

Core strength refers to over 35 muscles that attach to the "lower core" lumbo-pelvic-hip complex and the "upper core" spine, ribs and scapula region. When activated, and recruited properly, the stability of the upper and lower core form the foundation to all movements.

Joint stabilisation of the rotator cuff (shoulder), hip complex, ankle complex, etc. is imperative because they assist in optimising joint function during every action in tennis.

The better trained these muscles are, the more efficient the transfer of energy will be throughout the body, making the players quicker, more powerful, and most importantly decreasing the strain experienced by these muscles.

Core Stability Exercises

Stabilisation strengthening exercises rely on the player's ability to execute the recruitment and alignment perfectly, not just to do them.

This may be the most critical element of any young player's physical development, and the foundation for all higher performance training throughout their playing career.

EXERCISE 1: Ball Wall Squats

Equipment

- Physio ball

Directions

- Start with the ball against your lower back and the wall.
- Switch on your lower core at a low level.
- Keep knee behind toes. Keep load though the heels and compress ball into the wall.
- Start with 1-2 reps x 10 sets

Progression

- Increase to 2-3 reps x 20 sets.
- Increase leg strength and stability by gradually increasing number of repetitions and depth of squat.
- Progress to single leg squats when able.

EXERCISE 2: Side-lying Physio Ball Abduction

Equipment

- Physio Ball

Directions

- Lie on your side with a physio ball between your ankles
- Switch on your core
- Raise both legs up into abduction and hold for 2-4 seconds.

Progression

- Start off with 2 sets of 6 reps and progress as strength and ability allow to 3 sets of 10-12 reps.

EXERCISE 3: Squat Thrust

Equipment

- Physio Ball

Directions

- Lie over a physio ball with arms in a press-up position with shins on the ball, hands shoulder-width apart under the shoulders.
- Switch on your core to connect upper and lower body.
- Place knees slightly apart for stability. Set lumbar spine in neutral and ensure shoulders are stable with shoulder blades down and chest out.
- Pull knees to your chest and crunch the abdominals to get an extra flex of the hips and back.
- Hold for 4 seconds.
- Slowly extend knees back, using your abdominals to prevent the hips dropping down.

Progression

- Start off with 2 sets of 6 reps and progress as strength and ability allow to 3 sets of 10-12 reps.

PROPULSIVE STRENGTH

Propulsive strength refers to the type of training that elicits greater and more efficient intra (within) and inter (between) muscular motor unit recruitment by improving the summation and synchronisation of muscle fibres

This will facilitate the production of more force in less time (increased impulse), making players quicker and more powerful by storing and releasing greater amounts of energy than untrained muscle.

Given the proper hormonal response and nutritional support, the muscle will begin to increase its potential to generate force by increasing its size through a process of hypertrophy.

Hypertrophy in tennis players should be carefully guided so as not to put on non-functional weight. That is, every ounce of muscle added must produce more speed, power, or endurance for it to benefit the player.

ENDURANCE TRAINING

The role of aerobic and anaerobic endurance is particularly influential in clay court tennis and yet further pronounced among baseline players and those with energetically complex techniques (i.e. players who play with considerable spin and use aggressive body movement).

Basic Endurance Training

Running is, in relation to cycling and many other sports, clearly preferable for tennis players since the movement technique of running resembles the requirements of tennis play.

However, similar training effects for basic endurance can also be obtained through participation in other sports, as long as large muscle groups are activated, a dynamic motion is ensured and the movement technique is easily mastered.

To improve basic endurance the continuous training method is most beneficial. The continuous training method can be divided into the extensive and the intensive continuous methods. In prescribing training programmes, the extensive continuous method precedes the intensive continuous method, and comprises the largest part of the basic endurance training.

Extensive Continuous Training

- Recommended training duration amounts to 30-60 minutes (excluding warm-up and cool down).
- Energy supply is exclusively aerobic.
- Fat metabolism assumes 40-60% of the energy used.
- Should be performed three to four times a week within an endurance training block and at least once a week during tournament season.
- Adaptation effects of the aerobic metabolism system.
- Intensive Continuous Training
- Typically lasts 20-30 minutes.

- Should not be carried out more than twice a week as any more would compromise recovery (and the refilling of glycogen stores) and place the player at risk of over-training.
- Improves the maximum oxygen uptake of the player.
- Positive effects on the strength of will and the mental endurance of the player.

Control by Heart Rate

Heart rate can be easily used as a means of performance analysis and training control. Consequently, many players rely on formulas of the calculation of ideal, age-dependent training pulses. Without technical aid, the pulse is directly measured at the carotid artery (neck) or at the radial artery (wrist).

The experienced runner can monitor their pulse while running (pulse taken for ten seconds and multiplied by six), otherwise players should measure their pulse as soon as they pause; as having completed the workout one's heart rate will drop immediately. The use of a heart rate monitor provides for improved and more comprehensive training control.

Sensible formulas take age-dependent maximum heart rates into account as well as the individually variable resting heart rates. The individual training pulse for a basic endurance session for players should approximate 70% (extensive) and 80% (intensive) of the so called "heart rate reserve" respectively.

The heart rate reserve is defined as the difference between the resting heart rate and the maximum heart rate (220 minus age in men and 226 minus age women). The result of which is then added to the resting heart rate to attain one's individual training pulse.

Tennis-Specific Endurance Training

Training forms with different objectives are used for the purpose of tennis-specific endurance training on-court.

- **Type 1 (emphasises aerobic endurance):** Training forms that involve a high density of work and are performed at a sub-maximal intensity that is predominantly in the aerobic range. In these instances, the ball is continually played according to a given pattern between training partners (i.e. cross court rallies with a change in direction after each second or third stroke).

- **Type 2 (emphasises aerobic/anaerobic endurance):** Baseline competitions without service and return. The players must have a rally of three before the point is 'live' to ensure a high density of work.

- **Type 3 (emphasises anaerobic endurance):** Coach-centred drill training with intermittent work (i.e. 6-10 strokes on the run and under time pressure followed by active recovery over 30-45 seconds). This requires that players play common stroke combinations at the level of maximum metabolic matchplay demand. At the same time, tennis-specific speed endurance and will power are developed.

ALTITUDE TRAINING

Playing at Altitude

The higher you go in the atmosphere, the thinner the air. Thinner air means less oxygen, which makes it difficult to train intensely, and you may also suffer from acute mountain sickness (AMS). AMS effects can vary widely in the general population, and the severity depends on the elevation, the rate at which you reach the new, higher elevation, and your individual susceptibility.

The symptoms - headaches, loss of appetite, sleeplessness, and feeling sick - usually last only a few days at altitudes of around 3000 m; but at higher altitudes they can be severe enough or last long enough to interfere with training.

In addition, high air is extremely dry because water content in the atmosphere decreases with altitude. Furthermore, you breathe through your mouth in an effort to get enough oxygen, thus increasing water loss and losing the heat-conserving mechanism of the nose.

Exercising and competing at higher altitudes can have enormous performance consequences. Some of the immediate physiological effects of exposure to altitude are, increased breathing rate, increased heart rate and decrease in VO2max (maximal oxygen consumption).

The total effect of these adjustments is a reduction of work capacity. The higher the altitude, the greater the reduction. Performance at altitude is impaired in sports where aerobic power and where recovery that uses the aerobic system is important.

The Body's Adaptive Changes

When your body is subjected to a low oxygen (hypoxic) environment, adaptive processes attempt to facilitate the intake, transport, and utilization of oxygen. This is believed to occur through an increase in the number of red blood cells, which are produced in response to greater release of the hormone erythropoietin (EPO) by the kidneys.

The higher the altitude, the greater the stimulus to produce extra red cells. Red cells carry oxygen from your lungs to your muscles. More red cells mean your blood can carry more oxygen, which partly makes up for the shortage of oxygen in the air. Consequently, to compete at altitude, you should live at altitude for several weeks before the event.

Practical Implications for Players

1. Arrive as early as possible before competition to give your body time to adapt to the conditions.

2. Diet - A high carbohydrate, low salt diet allows for better adaptation and less risk of AMS. Some people experience significant decline in appetite and the resulting loss of muscle mass may hinder performance. Iron is used to make haemoglobin and the demand for making more red blood cells may require iron supplementation -- especially in women and vegetarians.

3. Fluids - Because mountain air is cool and dry you can lose a lot of water so be sure to maintain adequate hydration.

4. Adjust slowly – Do light exercise only on the first few days.

5. Alcohol - It is best to avoid alcohol consumption during the acclimatization period since it appears to increase the risk of AMS.

Training and Altitude

But what about when you come back to sea level? Will the extra blood cells supercharge your muscles with oxygen and push you along faster than ever? That's what should happen, but there are problems.

When you first move to altitude, the shortage of oxygen makes it difficult to train intensely, and you may also suffer from altitude sickness. If you don't adapt well to altitude, you may overtrain or lose muscle mass.

Even if you do adapt well, you still can't train with the same intensity as at sea level. The result? You detrain. When you come back down to sea level, you may do better or worse than before, depending on the balance between adaptation and detraining.

A potential solution to this problem is to live high, train low. There aren't many places in the world where you can live high and train low, so many athletes use methods to gain the train-low effect without coming down the mountain, or to get the live-high effect without living on a mountain.

Live High, Train Low

The research consensus is that living high and training low enhances any competitive performance that is limited by the ability of the athlete to consume oxygen. That means high-intensity events, lasting between a minute or two and several hours (such as tennis) will benefit from the live high, train low strategy.

The average athlete could expect an enhancement of aerobic performance of a few percent (2-3%) from living high and training low, but some athletes may get a bigger boost, while others may get no benefit at all.

It is highly impractical for many athletes to live at altitude and come down to train. Therefore, many athletes use methods designed to mimic the effects of the live high, train low strategy. These methods include:

- **Stay High and Train Hard with Oxygen**
  If the mountain does not offer the possibility of training low, an athlete may be able to do high intensity training on a sport-specific ergometer while they breathe oxygen-enriched air through a facemask.

- **Rest and Sleep in a Nitrogen Tent**

  Altitudes of around 2500 m can be simulated by reducing the oxygen content from the normal 21% to around 15%. A nitrogen house can be sited almost anywhere as a fixed or mobile facility.

  A mini version of a nitrogen house, in the form of a tent, can simulate altitudes of up to 2700 m (9000 ft) and can be modified to simulate up to 4000 m (14,000 ft). The tent is set up on a bed or on the floor. The advantages are substantial: it is truly portable; it can be used with little or no disruption of family life, study, or work; and it is easily the best way to establish the altitude and program of exposure that suits the individual.

  The units are expensive (US$5,500), but not dissimilar to the cost of a trip to a mountain and similar in price to other equipment used by top athletes.

- **Blood Doping**

  Enhancement of the oxygen-carrying capacity of blood (by increasing the number of red blood cells) is a well-known means of increasing aerobic capacity. While this is essentially what happens naturally when living at altitude, there also exist 'artificial' means of doing the same thing.

  Known as blood doping, injections of erythropoietin or blood transfusions also increase the red blood-cell mass that normally accompanies altitude exposure. With excessive use, both strategies are dangerous: the blood becomes thicker, and so increases the risk of sudden death from blood clotting.

  It is not a surprise therefore, that blood doping is prohibited by the World Anti-Doping Agency, and so also under the Tennis Anti-Doping Programme.

- **Ethics**

  There are two good reasons for banning a practice that enhances performance: either it causes illness or injury, or it gives the athlete a technological advantage that is too expensive or too new for most other competitors to use.

  Living on a mountain with frequent trips down to the valley is unlikely to be considered unsporting. But aside from the temporary altitude sickness, altitude exposure can be damaging to health in a small proportion of the population.

  Continuous exposure to altitude may lead to accumulation of fluid (edema) in the lungs and brain, which can be fatal. Furthermore, excessive production of red blood cells increases the risk of sudden death through blood clotting or a heart attack. However, the average athlete who spends a few weeks at a moderate altitude will not have these problems.

  Altitude chambers, nitrogen houses and nitrogen tents would be dangerous if the simulated altitude was high enough and long enough to raise the thickness of blood to an unsafe level. However, so far these devices are legal.

  Furthermore, these devices are unlikely to be banned as an expensive innovation, since they are no more expensive than high-tech training equipment used by many athletes. Can they be banned?

  Possibly not, because you can't ban normal altitude training, so it may be seen as unfair to ban a safe practice that makes it easier or cheaper for athletes to achieve the same effect. Still, it will be a sad day when athletes have to spend weeks of their lives in such apparatus to keep up with other competitors.