BIOMECHANICS FOR TENNIS

'The study of the mechanics of a living body, especially of the forces exerted by muscles and gravity on the skeletal structure'

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Introduction

A sound knowledge of biomechanics enables the coach to understand how the body can work most efficiently to achieve a desired outcome. There are several biomechanical principles that can be applied to all strokes in tennis. These principles can be applied logically to all situations and can help the coach find the most effective technique for each individual pupil.

It is important to note that biomechanics does not give the coach definite answers about technique, however, it does help *understanding* about how techniques develop and how they could be enhanced further. For example, biomechanics does not tell a coach which grip their players should use, however, an understanding of biomechanical principles does give a coach insight into why players use certain grips and how this impacts on the rest of their technique.

With an understanding of biomechanics a coach may make different technical interventions with two players that use the same technique. This would be because the outcomes that the players were trying to achieve would be different (e.g. more power or more control). The coach would be able to use their knowledge to make the correct intervention for each player.

'Knowing what body motions were used and how they were created and may be modified are powerful tools for improving performance and reducing the risk of injury in tennis'

Knudson, Biomechanical Principles of Tennis Technique, 2006

There are several biomechanical principles that academics have studied. This resource considers the ones most relevant to tennis, and how they affect a tennis coach's day-to-day teaching. These principles are:

- Balance
- Inertia
- Force and time
- Opposite force
- Momentum
- Co-ordination chain (including elastic energy)
- Range of motion

Balance

Balance is the ability to control a body's motion. It is critical in a sport such as tennis which requires large amounts of movement, but also requires accuracy and consistency.

In tennis it is not just about finding the most balanced position. This is because stability and mobility are *inversely* related. In other words, the most balanced and stable positions are also the ones that are the most difficult to move quickly from! Tennis, therefore, is about finding the right compromise between stability and mobility. Related areas to be aware of are:

The centre of gravity
This is the (imaginary) point around which the mass of the body is distributed. The human body is not symmetrical, neither is its mass evenly distributed - even at rest. The centre of gravity will move with different body positions and will be constantly changing position with a moving tennis player.

The key point here is that the position of the centre of gravity influences the *stability* of the player. If it is high, the player is less stable. If it is low, the player is more stable. Tall male players have to work hard on their balance because their centre of gravity is high and, therefore, more difficult to control.

The size of the base
This is the base of support of the player. It is not just the position of the feet which determines the base but the area of ground *between* them. As a player increases the size of their base they become more stable.

In order to move, a player must shift their centre of gravity beyond the limits of their base. At this point they start to topple over - although instead of falling the player brings a foot through to regain stability and in doing so *moves*.

A player has to find the optimum base for them in each situation. On returning serve, a wide base in the split step gives stability - but too wide and they will not be able to move quickly enough to the return!

Balance is a factor in every tennis stroke and players must maintain control of it as much as possible. A player's balance is constantly being challenged, however, because of the forces involved and the demands of the game.

A player's balance will be affected when a force is applied to the body. If a player is quite upright when they hit a stroke they will often lose balance when they apply force to their stroke. A player using a wider, lower base will be more able to maintain balance while applying force to a stroke.

Inertia

Inertia is a body's (or a segment of a body's) resistance to change in its state.
Moment of Inertia is a body's (or a segment of a body's) resistance to rotate. A body's inertia is directly related to its mass. In other words, if an object is very heavy it has a greater reluctance to move than an object half its weight.

A body's moment of inertia is more related to how its mass is distributed in relation to its axis of rotation. If an ice skater brings his or her arms and legs in close to the body then they would rotate more quickly. This is because the mass of the arms and the legs had been brought closer to the axis of rotation - hence *decreasing* the skater's moment of inertia.

Examples of this principle in tennis:

- A player will tend to use a looped take back on ground strokes. One of the reasons for this is that the racket does not have to stop before starting a forwards swing. This prevents the racket from developing inertia that the player would have to use *force* to overcome.

- On a slice approach shot down the line, a player wants to hold a sideways-on position. If they were to rotate they would be more likely to miss the shot (by swinging ‘across’ the ball). The player stops themselves rotating by swinging forwards with the racket arm and back with the non-racket arm. This puts mass further away from the potential axis of rotation and *increases* the player’s moment of inertia. This helps the player hold their sideways-on position.

- A young player trying to use a full size racket will often slip to an extreme western forehand grip. One of the reasons for this is that they want to have the racket as close to the body as possible – because it will *reduce* their moment of inertia and make it easier to rotate through the shot. As the contact point comes closer in to the body, the more extreme forehand grip becomes the only practical way to hold the racket and still achieve a sound contact point.

Force and Time

The force and time principle states that the motion of any body can be modified by the application of force(s) over a period of time. Most movements in tennis involve large forces being applied over a short space of time – due to the nature of the game. This is where Newton’s three laws of motion come into play:

Newton’s 1st law

Force has to be applied to overcome a body’s inertia. For linear movement, the greater the mass of the body the greater the force that is needed.

Newton’s 2nd law

The acceleration of a body is a result of the sum of all the forces applied to it divided by its mass. Therefore, how much a body can be accelerated depends on how much force is applied to it and its mass - i.e. the greater the force the greater the acceleration. However, as mass increases a body becomes more difficult to accelerate.

Newton’s 3rd law

For every force, there is an equal and opposite force acting in the opposite direction from the other body.

Examples of these principles in tennis:

- It is possible for a player to hit a ball so that it travels very fast. This is because the player’s body combines to create a *large* force that is applied to the ball which has a very *small* mass.

- A tennis player has a fairly significant mass. So, in order to set off quickly to run for a drop shot, a very large force needs to be applied over a short space of time to overcome the body’s inertia and to then accelerate quickly. The player does this by pushing his/her legs into the ground in the *opposite* direction to which he/she wants to move. As the player pushes into the earth - the earth pushes back at the player (3rd law). As the earth has a far greater mass than the player, the force is significant enough to change the velocity of the player, but is nowhere near enough to change the velocity of the earth!

- A player uses a split-step when they need to react quickly and move fast. When a player split-steps they are pushing down *against* the ground. The ground pushes back against the player, and again, the player having less mass than the earth is able to move off quickly.

- When a player hits a ball they are applying a large force to the light ball. The ball applies a large force back on the player. The ball, having a light mass, accelerates quickly. The player with a bigger mass is hardly affected – although the lighter racket will have some 'recoil'.

Momentum

A body's momentum is a combination of its mass and velocity. The formula is:

Momentum = mass x velocity

In a motion, the amount of momentum will remain the same. Therefore, if mass increases the velocity will decrease - and vice versa.

The main implication of this principle is that when a player is looking to produce power they need to get the biggest muscles (i.e. biggest part of the body such as legs and trunk) moving first. During the stroke, the energy is transferred to the smaller muscles and limbs such as the arm and the hand. The mass has now *decreased* and, as momentum remains constant, the velocity has to *increase*.

Co-ordination Chain

The use of the body parts and muscle groups on a sequential (or chain link) basis to develop force is significant in pretty much all tennis movements and techniques. The body is able to apply a significant external force on the tennis ball only after a complex co-ordination and transfer of *energy* between the various linked segments of the body.

The transfer of energy through a co-ordination chain is still not fully understood. There are, however, some useful issues to be aware of. For example:

Pre-stretch

Energy is created in the body by the muscles stretching and then firing. The most simple, and probably the best analogy is to think of an elastic band, or catapult, that has to be stretched before it can be fired. This is known as the 'stretch – shorten cycle', but is most commonly referred to as 'pre-stretching' the muscles.

Pre-stretch of the muscles occurs in pretty much all areas of all strokes. For example:

- When the legs bend before a big forehand or serve – the leg muscles are pre-stretched, ready to drive into the shot.

- When the shoulders turn further away from the ball than the hips on ground strokes and serves - this pre-stretches the muscles across the trunk of the body.

- As the hips drive into the stroke on the forehand - pre-stretch is created across the shoulder.

Coaches need to be aware that elastic energy cannot be stored in the muscles for *long* periods of time (as it could be in an elastic band). After about half a second of being on pre-stretch the muscle starts to fatigue and lose energy. Implications of this are as follows:

- A player might take the racket back too far too early and pre-stretch the shoulder long before the ball has arrived. This would not be efficient use of energy.

- A player might bend the legs too soon when setting up for a forehand. The leg muscles would fatigue and energy would be lost.

This is often referred to as *dissipation* of elastic energy.

From the ground up

The energy used in nearly all tennis strokes starts from the player pushing into the ground and the ground pushing back at the player (opposite force). The muscles then need to fire in a coordinated sequence, and invariably this sequence starts with the big muscle groups of the legs – then the trunk – the shoulder – the arm, etc.

Sometimes, one segment of the coordination chain can fire out of sequence and the chain will no longer work efficiently. When this occurs the player has to compensate by forcing the stroke with the last few links in the chain. As a result, the player will be inconsistent, may lack power, and will be more susceptible to injury.

An example of this would be on the serve. A common mistake (often due to a poor ball placement) is for the back leg and hip to 'come through' too early – i.e. before the leg drive. The hip coming through too early 'breaks' the coordination chain and results in no energy being contributed to the stroke from the lower body and trunk. This leaves the shoulder and arm to do all the work! Typically, a player that does this would lack power in their serve and may develop an injury to their shoulder or elbow.

As one muscle group fires it increases the displacement of the next limb and increases the *pre-stretch* in the related muscle group. It is important to realise that all the muscles involved in a coordination chain do not pre-stretch at the same time. As one muscle group fires and accelerates the associated limb – the next limb in the chain is ‘left behind’. This is referred to as *displacement*. The displaced limb puts the next muscle in the chain on stretch. It is then able to produce lots of energy quickly - with the limb forced to accelerate to ‘catch up’. When all done correctly the final part of this is the racket head accelerating to the contact point.

An example of this is seen on the serve. As the legs drive upwards and the hips start to fire – the racket head drops down the player’s back. This *displacement* of the racket head puts the shoulder on stretch – creating elastic energy. The shoulder muscle is then able to fire and the racket head is able to accelerate very quickly up towards the contact point.

Range of Motion

The range of motion principle explains that when high speed is required (attacking forehands and serves for example), more segments should be used in the coordination chain and that each segment should have a larger range of movement. When accuracy is required (volleys and return of serves for example), less segments are used, and the segments that are used will have a smaller range of movement.

It is important to understand this principle, however, coaches must also recognise that in tennis both power and accuracy are needed. It is not as straight forward as saying that if the player requires more power they should use more segments and for more control less segments. For example:

- If a player tries to generate power by having lots of segments working over a large distance, but as a result, miss-hits the ball - then they will produce *less* ball speed than they would with a more simple action and a better-timed hit.

- Conversely, a stroke could become *more* consistent by increasing the number of segments. This is because if the player is only using a few segments, those segments could be working *too* hard to hit the ball. If a segment is working too hard then it will not work as accurately, and the player will be inconsistent.

Conclusion

Having sound knowledge of biomechanics will aid every coach in their day-to-day teaching of tennis. Crucially, it provides the coach with greater insight into technical analysis and intervention, as well as enhancing their understanding of physical motion across all sports.

This resource is one of a range specifically produced for tennis coaches by Rob Antoun and Dan Thorp of Pro Tennis Solutions Ltd. Other resources include:

- ***Technical Analysis for Tennis***
- ***Coordination and Movement Training***
- ***20 Core Drills for Tennis***
- ***Singles Tactics for Tennis***

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