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UNDERSTANDING TECHNICAL ERRORS IN TENNIS THROUGH KINETIC CHAIN ANALYSIS

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Abstract: *In tennis, errors that appear now of ball contact are frequently interpreted as isolated technical faults. However, many of these visible mistakes originate earlier in the kinetic chain. This paper discusses how disruptions in movement efficiency and muscular stiffness can alter the sequence of energy transfer within the kinetic chain and ultimately lead to late contact points during tennis strokes. Looking at the importance of movement toward the ball, body alignment, and neuromuscular coordination, the study highlights how small inefficiencies in early phases of motion can propagate through the kinetic chain and affect stroke execution. In this article it is also discussed the practical implications for coaching, analysed the importance of biomechanical observation and video analysis for identifying the true origin of technical errors. This paper aims to explain how movement, balance, and timing interact within the kinetic chain and help coaches and athletes identify the main cause of technical mistakes rather than focusing only on their final manifestation.*

Key words: *tennis biomechanics, kinetic chain, stroke mechanics, movement efficiency.*

1. Introduction

Tennis has been considered one of the hardest sports to learn and master because it demands a combination of physical, mental and technical abilities that need to be used all at once. Being an individual sport makes things even harder, while on other sports athletes can rely on their teammates, on individual sports the accent is on the player itself.

In the recent period, tennis has evolved a lot, it became more physically demanding, faster and more technology oriented. What was considered fast in the early 2000's now it is considered slow.

The sport evolves and we need to adapt.

This highlights how modern tennis places greater demand on timing, anticipation, reaction speed and especially on efficient movement. As the ball speed increases, players have less time to react [13], [8], less time to organize their movement and stroke, making early preparation and proper positioning in relation to the ball key components of performance.

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In the context of this paper, the kinetic chain refers to the sequence in which body segments work together to transfer energy starting from the ground through the body towards the racket.

For example, a late contact point in tennis strokes is often interpreted as a timing error, but in many cases, it is the result of a disruption earlier in the kinetic chain [3], [10].

If the stroke itself follows its normal course but the contact point is late, the first thing to examine is not the racket or the arm. It is the movement toward the ball, and then the organization of the body during that movement: the ankles, knees, torso, shoulders, arms, and even the head position.

In many cases, this type of problem comes from two main factors:

- inefficient movement toward the ball
- muscular stiffness that breaks the kinetic chain

However, in many chases this type of error is treated as a contact point mistake without being taken into consideration that the origin of the mistake lies earlier in the kinetic chain rather than at contact point itself.

The aim of this paper is to analyse how disruptions in the kinetic chain affect the quality of the stroke and to demonstrate how biomechanical analysis can help identify and reduce these mistakes.

Strokes occur very quickly, and the human eye, even though it can react at incredible speeds, is sometimes not enough to detect small disruptions within the movement.

When the kinetic chain is analysed, fixed reference points from video recordings can facilitate interpretation and make the analysis much easier to perform.

By slowing the movement down and observing different phases of the stroke, coaches can identify where the sequence of the kinetic chain begins to change. Preparation timing, body alignment, and base stability become much easier to observe when the movement is analysed frame by frame [7].

In many cases, the mistake that appears now of impact actually originates earlier, during movement or preparation, and video analysis can help reveal those small disruptions that are difficult to detect in real time.

2. Material and Methods

2.1. Study design

This present study is based on a qualitative biomechanical analysis of tennis strokes, using video recordings and Factorial Biomechanics software to evaluate movement patterns and segment coordination.

The study follows a qualitative observation design focusing on the biomechanical analysis of tennis strokes through segmental coordination and kinetic chain sequencing. The objective was to identify differences between strokes executed with an optimal contact point and those with a delayed contact point, emphasizing disruptions in movement patterns and energy transfer.

From a biomechanical perspective, analyzing the movement as a sequence rather than isolated actions allows a better understanding of how technical errors develop. In tennis, the quality of the stroke is not determined only by the final segment, but by the entire coordination between body segments involved in the kinetic chain.

By approaching the analysis in this way, it becomes possible to identify the exact phase in which the disruption appears, whether it is during movement, preparation or execution. This type of analysis provides a more complete view of the stroke and helps differentiate between visible errors and their actual origin within the movement sequence.

2.2. Participant

The analysis was conducted as a qualitative case study on an active tennis player with competitive experience. The player was clinically healthy and had no recent injuries that could affect movement execution. The use of a single subject allowed for a more detailed observation of segmental coordination and subtle changes in movement patterns that may be difficult to identify in group analysis.

2.3. Equipment and instruments

Video recordings were obtained using a Samsung S25 Ultra camera, recorded at 120 frames per second in Pro Video mode. The camera was positioned laterally relative to the player, allowing observation in the sagittal plane. The recordings were processed using Factorial Biomechanics Software, which enabled frame-by-frame analysis and evaluation of segmental movement throughout the stroke.

The high frame rate allowed a more precise observation of movement phases and facilitated the identification of small variations in timing and segment coordination.

The camera was placed at an approximate distance of 3–4 meters from the player, ensuring that the entire body was visible throughout the movement. The recording was performed from a lateral perspective, allowing a clear observation of the sagittal plane and facilitating the analysis of segmental sequencing within the kinetic chain.

2.4. Procedure

The player executed multiple one-handed backhand strokes under similar conditions. The movements were recorded and later analyzed by identifying key phases of the stroke, including preparation, loading, trunk rotation, weight transfer, impact, and follow-through. Special attention was given to the sequencing of body segments and the timing of energy transfer within the kinetic chain.

Each stroke was repeated multiple times to observe consistency in movement patterns and to reduce the influence of random execution errors. The analysis focused on identifying similarities and differences between repetitions, allowing a clearer understanding of how the kinetic chain behaves in different situations.

The recording conditions were kept constant throughout the analysis, ensuring that variations in movement were caused by the player’s execution rather than external factors. This allowed a more accurate observation of the relationship between movement, timing and contact point.

During the execution, particular attention was given to the consistency of the movement and the ability to reproduce similar stroke patterns. This allowed a clearer distinction between stable movement characteristics and variations caused by timing or positioning errors.

2.5. Variable analyzed

The analysis focused on several biomechanical variables, such as segmental synchronization, trunk rotation, base stability, contact point position, and the presence of compensatory movements, particularly at the level of the wrist.

Additional emphasis was placed on the relationship between movement efficiency and timing, especially in situations where the contact point was delayed. The interaction between different variables was also considered, as changes in one segment of the body often influence the behavior of other segments within the kinetic chain.

The relationship between lower body action and upper body involvement was considered, especially in terms of how efficiently the energy was transferred from the ground to the racket. The presence of delays or interruptions in this sequence was used as an indicator of disruption within the kinetic chain.

2.6. Data analysis

A qualitative comparative analysis was performed between strokes with optimal contact and those with delayed contact. The aim was to identify disruptions in the kinetic chain and observe how these affect movement efficiency and stroke execution.

The analysis also aimed to identify recurring patterns in the execution of the strokes, rather than isolated mistakes. By observing multiple repetitions, it was possible to determine whether certain errors were consistent and linked to specific phases of movement.

The comparison between optimal and delayed contact points was not limited to the moment of impact, but extended to earlier phases of the movement, allowing a more complete understanding of how the error develops throughout the kinetic chain.

This type of qualitative analysis allows not only the identification of errors, but also a better understanding of how they develop over time and how they influence the overall efficiency of the movement.

The analysis was focused on understanding the origin of the error rather than only its visible manifestation now of contact.

3. Results and Discussions

In tennis, compensation almost always appears somewhere in the kinetic chain. When one segment of the movement is disrupted, another segment reacts to complete the strike [10].

If the contact point is late the body rotation most of the times needs to compensate for the ball to reach an appropriate speed and maintain control.

On the tennis court, efficient movement is just as important [14] as technique or mental preparation.

If the movement toward the ball is not efficient, the player arrives with an unstable base. When the base is unstable, the body cannot generate and transfer energy correctly through the kinetic chain. The result can be a contact point that is either too early or too late [6].

When a player starts moving toward the ball, especially during a sprint, the body generates a large amount of kinetic energy. That energy is maintained while the movement continues and is released when the player slows down or stops.

The moment when the movement stops is the moment when the stored energy can be redirected into the strike. If the movement is well balanced and well timed, that energy flows through the body and into the shot.

But if the movement is poorly timed or unbalanced, the energy generated by that sprint is simply wasted. Worse than that, it disrupts the kinetic chain.

And when the kinetic chain is disrupted, the result is often exactly the problem we started with:

- a late contact point.

For the elastic force to function effectively muscles must remain relaxed or minimally activated during the loading phase, allowing the transition into acceleration to be smooth and coordinated.

This will cause a slight delay in the motion of the kinetic chain [5]

From a coaching perspective, the interventions should not focus only on the contact point for example, but rather on the whole action made to produce a stroke. The quality of the stroke is directly influenced by all the elements involved before the stroke happens in the kinetic chain, like efficient footwork, early preparation and proper body positioning.

Encouraging players to practice relaxation during the loading phase and avoiding unnecessary muscle tension can help improve the use of elastic energy and overall movement quality. By training players to move effectively and maintain a proper timing, coaches can reduce the need for compensatory actions and help develop more consistent and controlled strokes.

These principles can be observed in specific stroke situations, where even the small disruption in the kinetic chain leads to visible changes in performance.

Let's take as an example a player that hits one handed backhand. The one-handed backhand is having some extraordinary particularities and many times the strike looks tame, the preparation looks the same, yet the outcome is different.

The one-handed backhand relies [12] on an efficient use of the kinetic chain and effective distribution of elastic energy through the stretch-shortening cycle [7]. During the preparation phase, when the energy is accumulated and stored in the muscles and tendons, the player is creating a pre-stretch within the muscle groups of the lower body and trunk. The energy that was accumulated during the pre-stretch phase will be released in the kinetic chain during the forward swing phase which leads to an increased speed of the racket head without using excessive muscular effort resulting in a whip-like effect.

To be able to create an efficient stroke it is necessary to have a proper timing and sequencing between body segments [10]. Energy is transferred from ground to legs (ground reaction forces), into the trunk (trunk rotation and elastic recoil) and finally to the arm and racket (the whip like effect) in a proximal to distal sequence.

If we analyse this sequence, we will realise that each component plays a specific role in the production and transfer of the energy. The process begins with the interaction with the ground, where the initial forces are generated through the legs. This phase is fundamental as it represents the initial source of energy that is created, stored and later transferred in the entire kinetic chain.

The energy travels from the legs to the trunk, where rotation and elastic recoil mechanism occur. During this phase the trunk and core muscles undergo a pre-stretch action, allowing energy to be stored and later released through the stretch-shortening cycle, a process that amplifies the force produced by the lower body and ensures an efficient transfer toward the upper body segments.

In the final phase the energy reaches the upper body where is transmitted through the arm and racket. The arm does not act as the main force generator, but rather as the last transmitter of energy coming from the previous segments involved in the kinetic chain. The result of this is a progressive acceleration of the movement and the whip-like effect, characteristic to the proximal to distal sequencing of the kinetic chain, which allows the racket head to reach a high speed with minimal muscular involvements.

For the one handed backhand to be executed smoothly, efficiently and effortlessly the whole kinetic chain must be aligned to the last detail [11].

If the player starts preparing for the strike late, the contact point will also be late. If the player reaches the ball late, the strike becomes unbalanced.

For the one-handed backhand balance is key because the strike relies heavily on timing and body alignment, even a very small delay in preparation or movement can affect the entire kinetic chain.

I want to add here that a stiff body will result in stiff and heavy movements. Regarding the matter described earlier, speed cannot reach the highest level of efficiency while the body is tired.

Muscle stiffness in many cases comes from the body being tired or exposed to repetitive high-endurance training.

When the muscles are stiff, movement tends to be slower (as neuromuscular coordination decreases).

From a biomechanical point of view, this also affects the use of elastic energy within the kinetic chain. Muscle stiffness limits the efficiency of the stretch-shortening cycle, as the muscles and tendons are unable to store and release as much energy as in optimal conditions, the muscular system becomes more rigid, reducing the quality of elastic response.

In addition, excessive muscular tension restricts joint mobility and reduces the range of motion, preventing the body from achieving the optimal position during the stroke preparation. This limitation affects the loading phase of the kinetic chain, where the elastic energy should be accumulated and disrupts the flow of the energy through the stroke by limiting the transition into acceleration.

Another negatively influenced process is the intermuscular coordination, make it more difficult for body segments to work together in a synchronized manner [15]. As a result, the timing between the segments becomes less precise and the energy transfer through the kinetic chain is compromised. Movement becomes slower, shorter and less fluid, leading to decreased racket head speed and power [15].

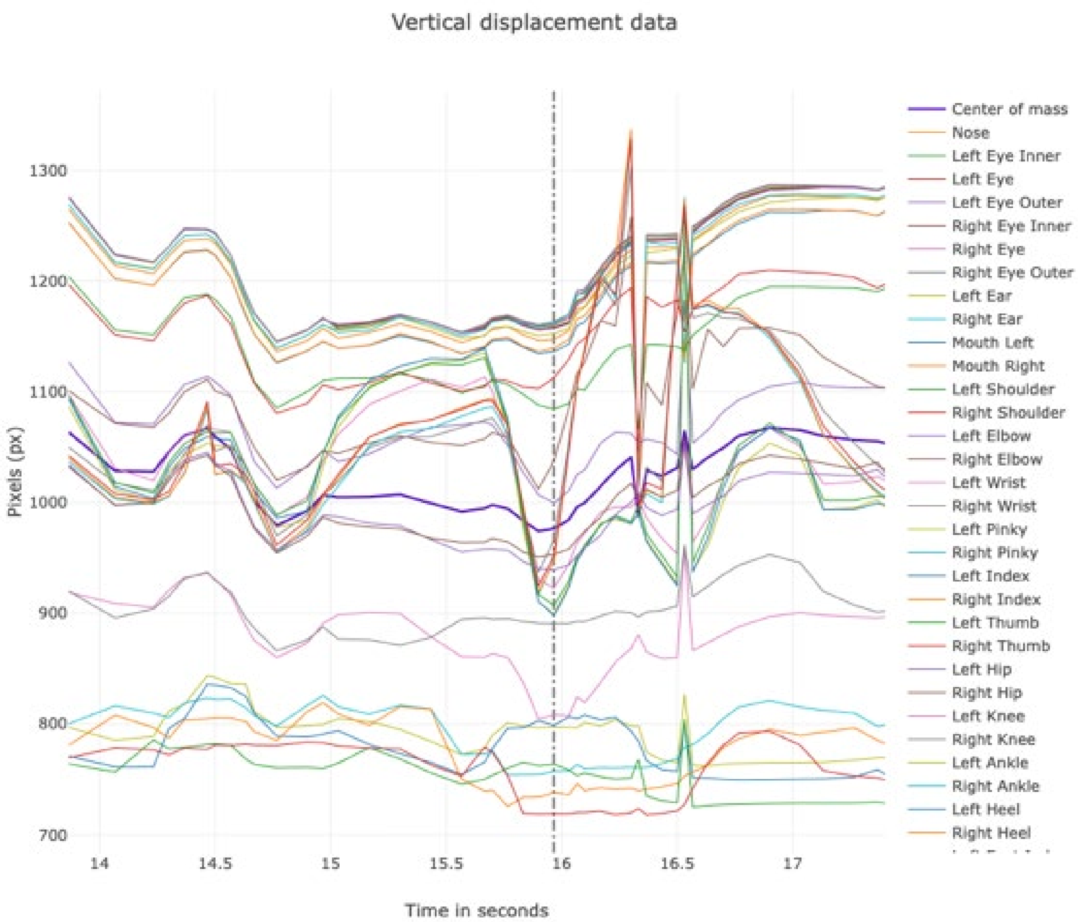

Fig.1. *Vertical displacement of body segments during a stroke with a late contact point*

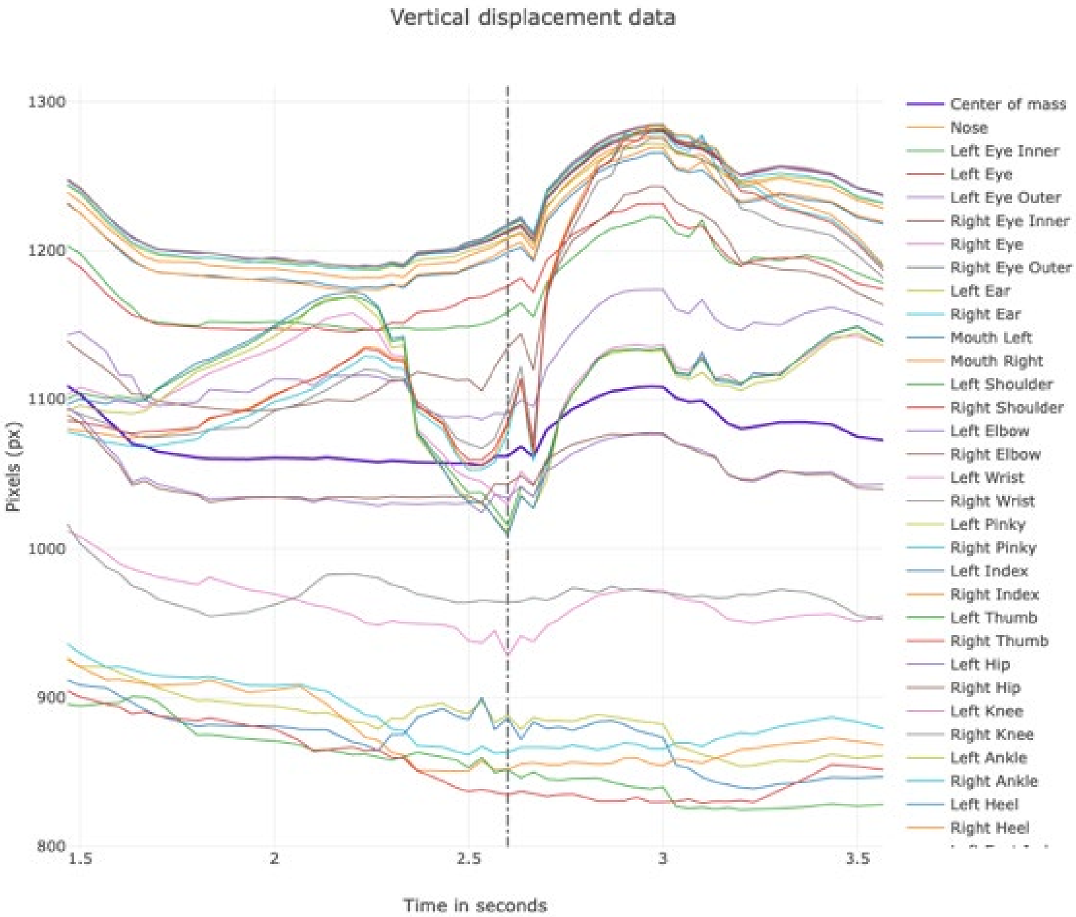

Fig. 2. *Vertical displacement of body segments during a stroke with optimal contact point*

The difference between the optimal contact point and the late contact point can be observed through graphical analysis of segment displacement. The graphic representation helps to better observe the difference between body segments and how the kinetic chain is affected by the late contact point. As shown in Figure 1, the body segments appear less synchronized, with visible irregularities and delays in the segment of movement.

In Figure 2 we can observe a more coordinated and progressive movement [2] which indicates a smooth energy transfer through the kinetic chain, from the lower body segments to the racket.

Another important chain reaction that appears [4] in this context is that a contact point is late it forces the body to compensate and the neuro-muscular system reacts by increasing the muscular tension in order to stabilize the strike.

A common compensatory mechanism observed in tennis appears when the wrist is excessively used. When the contact point is late or the kinetic chain is not functioning efficiently players tend to compensate by actively using the wrist segment to generate speed or to gain control. This results in an exaggerated wrist flexion described as wrist snap, which disrupts the overall force production of the stroke. From a biomechanical perspective, the wrist movement should be largely passive especially in strokes such as the forehand characterized by an initial extension called racket lag followed by natural release toward a natural position because of the kinetic chain. When the natural wrist pattern is replaced by active compensation, it increases the muscular tension, reduces efficiency and negatively affect power and control.

4. Conclusions

In tennis, what we see now of impact is often the result of a mistake that happened earlier in the kinetic chain and later affects movement and efficiency because of compensation within the motion chain.

If we pay more attention to details, we can identify the issues players are having much faster and solve them more precisely with less work.

All we need is better knowledge and a deeper understanding of the tools that years of sport science and tennis analysis have given us.

Otherwise, we may continue correcting only the visible mistake while the real cause remains somewhere earlier in the movement.

If not, we will still end up having faults and mistakes in a chain reaction… or should I say, a kinetic chain reaction?

In addition, it is important to consider that modern tennis places increasingly higher demand on players in terms of coordination, speed and physical efficiency.

The pace of the game has increased drastically over the years; the margin of error is smaller and even the smallest disruption in the kinetic chain can affect performance. This highlights the importance of developing efficient movement patters and ensuring proper sequencing of body segments during stroke execution.

From a practical point of view, understanding how energy is produced and transferred through the kinetic chain allows players and coaches to focus on the actual source of the problem not just on the visible result now of impact. Many technical errors, such as a late contact point or lack of control are often consequences in the earlier disruptions in timing, coordination or positioning towards the ball. By improving these components, the player can achieve a more natural and efficient movement, reducing unnecessary muscle stress.

This approach reflects how biomechanic principles can be applied in practice to improve performance in a structured and effective way.

These observations confirm that even small disruption in the early phases of the kinetic chain can affect the final outcome of the stroke, therefore, biomechanical analysis plays a crucial role in understanding the key mechanisms of mistake avoidance and player improvement.

Another important aspect is the ability to apply this understanding in real training conditions. When players and coaches are aware of how the kinetic chain functions, they can approach technical correction in a more structured and efficient way. Instead of focusing only on the visible mistake, they can identify the phase where the disruption begins and addresses the root cause of the problem.

This approach not only improves performance, but also helps reduce unnecessary physical stress, allowing for a more natural and sustainable development of the player.

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