# MOVEMENT-PRODUCTION STRATEGY IN TENNIS: A CASE STUDY

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## ABSTRACT

Gillet, E, Leroy, D, Thouvarecq, R, Mégrot, F, and Stein, J-F. Movement-production strategy in tennis: a case study. *J Strength Cond Res* 24(7): 1942–1947, 2010—The present case study fell within the framework of the "absolute approach of expertise" because it assesses a "truly exceptional individual" (Chi, MTH, *Cambridge Handbook of Expertise and Expert Performance*, London, United Kingdom: Cambridge University Press, 2006, pp. 121–130). This technique analysis examined the movement-production strategy used by a professional tennis player performing serve–return strokes. This research enabled us to establish the relation between tennis serve–return technique and successful performance. An optoelectronic system was used to capture and analyze the expert player's stroke production in a live situation to determine the temporal trajectory of the serve–return initiation movement. Some differences between the serve–return shots were observed concerning the occurrence time of the lateral racquet displacement, the amplitude of the racquet movement, and the average latency time. No difference was observed for the gravity center (GC) movements. Backhand, forehand, and reprogramming strokes were executed with a general constancy of occurrence and average times of the GC and racquet movements. This expert player used a predictive movement-production strategy specified by a high level of reproducibility of the movement with nevertheless adaptive skills during reprogramming strokes. This adaptation supported either the development of highly consistent motor programs or the use of a more flexible strategy based on the perception–action coupling.

**KEY WORDS** perception, predictive control strategy, reproducibility

## INTRODUCTION

Technique analysis is a method used to understand the way in which sports skills are performed. This analysis provides the basis for improved performance (13) and enables one to inform the coaching process (8). Lying within this framework, the purpose of the present study was to analyze serve–return strokes performed by an expert tennis player to provide a kinematics and temporal description of movement and to facilitate remediation and feedback about performance kinematics.

Tennis is an activity that implies high time constraints and requires coincidence-anticipation skill (18). In the modern tennis game, the serve and the return are important standardized movements of world-class players that may have a significant bearing on the result of the match. The receiving players have to cope with very high time pressure caused by the high serve velocities (up to 200 $\text{km}\cdot\text{h}^{-1}$) and high degrees of uncertainty. In fact, the men's tennis game has reached a threshold in the speed of the serve where reaction times are longer than the time available to return the serve. During that time, the receiver has to get organized to defend a space of 8-m width and play a stroke whose execution frequently spans less than 10 milliseconds (14). The serve return is considered as a particular shot that requires a technique of its own and differs from a normal forehand and backhand groundstroke (20). The few technical analyses (kinematics or biomechanical) that examined this task investigated the preparatory behavior of the receiver to describe the basic movement sequences (10) and to specify the split step–landing phase (1,20). The key factors of a successful return of serve are the timing of the movement preparation and the optimal initial position reacting on the velocity and direction of the moving ball during the serve (20).

Technique analysis can focus on the position variations of body segments. These position variations are characterized by various spatiotemporal parameters (e.g., speed, amplitude) that constitute motion adaptation indicators with respect to different interceptive task constraints (16) such as the serve return shot. The degree of consistency in the movement kinematics was a source of debate when the backswing and the forward swing of the movement were separately considered. First, a predictive control strategy on the movement

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time, such as the "operational timing" hypothesis (19), has been used to interpret the fundamental role of the movement initiation timing in the success of an interceptive task. Performers were assumed to develop highly consistent motor programs, needed only to predict the moment of movement initiation, in skill reproduction (6). Second, in a more ecologically valid setting, Bootsma and Van Wieringen (3) showed that the variability in the racquet positions of expert table tennis players was greater at the initiation of movement than at the moment of ball contact implying that the expert players did not fully rely on a high consistent movement-production strategy. The variability in the experts' initiation movement time was closely coupled to the variability inherent in the acceleration of the swing. This compensatory variability was considered as functional, implying a continuous visual guidance of the movement trajectories. Expert players used a "funnel-like type of control" (i.e., prospective control) to accommodate the movement from the initiation to the moment of the ball contact (3,12).

Technique analysis can also be provided by the simulation of human body models that allow the behavior of the modeled system to be simulated under different conditions. Then, simple point mass models of a skill can be used to establish some of the basic characteristics of technique and the effect of technique on performance (13). Vertical displacement of the gravity center (GC) of the human body has been presented as an excellent tool in human movement analysis because it reflects the biomechanical performance of the whole body (15). Considering the severe time-constrained serve–return task, this technical analysis describes the relation between the "split step–landing" phase and the initiation moment of the racquet swing. We also hypothesized that this expert player performs its serve–return strokes using a high consistent movement-production strategy that was characterized by a relative consistency of lateral and vertical displacements initiation of both its GC and its racket whatever the type of serves executed.

## METHODS

### Experimental Approach to the Problem

The current study is a "quantitative technique analysis" (13) to identify the key factors that affect the specific sequence of the tennis serve–return movement such as the split step landing and the backswing phases. This approach is based on the 3D capture and analysis of movement in a live situation. This case analysis falls within the framework of the "absolute approach of expertise" because it assesses a "truly exceptional individual" to understand a superior performance that can be adapted as an "index of expertise" (4).

### Subjects

A world-class male tennis player agreed to participate in this experiment that was approved by the Ethics Committee of

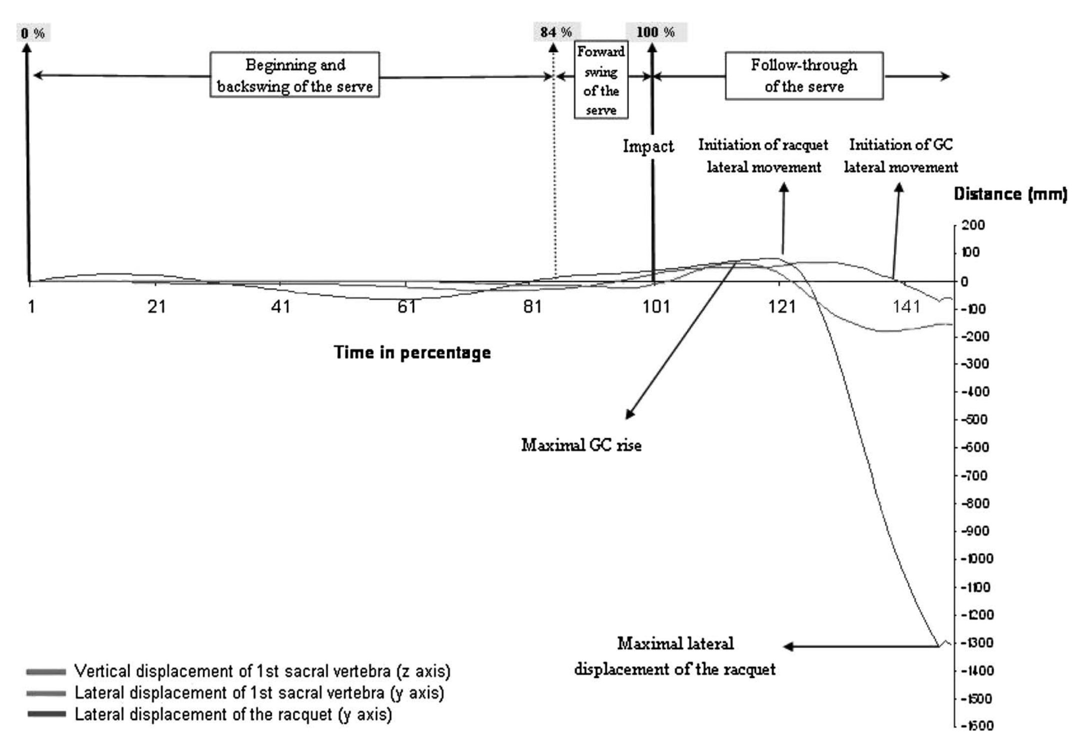

**Figure 1.** Mean spatiotemporal sequencing of forehand stroke production by the expert player.

the University (age = 23.00 years; experience = 15 years; body mass = 90.00 kg; and height = 188.00 cm). This expert player practiced about 17.00 h·wk$^{-1}$ and played an average of 320 international tournament matches. His best Association of Tennis men Professional world ranking was seventh.

**Procedures**

An optoelectronic Vicon Peak 612$^{TM}$ system with 6 cameras V-cams operating at 200 Hz was used to define a calibration space of 26.00 m$^3$ (4.65 long × 2.75 wide × 2.00 high). Thus, the full delivery player's action could be captured. This system recorded the 3D coordinates of hemispherical, infrared reflective markers attached to the receiving player and their racquet to measure the amplitudes and positions of the GC estimate and their racquet displacements. The lateral and vertical GC displacements were estimated from those of the first sacral vertebra. The external marker placed over the sacrum was used to represent the "total body GC" and consequently the global motion of the players (15). A reflective marker was positioned on the head's top of the racquet.

The player was positioned on a tennis court in its favorite return position (i.e., 1.20 m from the baseline and 1.05 m from the singles sideline). After calibration procedures, the player performed serve–return strokes as many deliveries as required to become familiar with the test environment. He executed double-handed backhand returns. He was instructed to perform successfully either backhand or forehand strokes, depending on the serve delivered from the deuce side. Two expert players executed several series of serve strokes to simulate a match play situation by combining first and second serves, ball spins (flat: minimal spin on the ball; topspin; and slice: sidespin) and locations in the service box (wide near the service sideline, into the receiver's body, and on the "T" near the center service line). Variation of serves permitted one to maintain the high spatiotemporal and uncertainty constraints of the serve–return sequence in the modern tennis game (7). Moreover, a digital video camera (Sony TRV 50 Hz, Sony Corporation, Tokyo, Japan) placed behind the receiving player was synchronized with the Vicon system to record the servers' actions. Thus, the duration of each serve could be measured to determine a temporal scale of all serves.

Given the most often used serves of high-skilled players, we limited our analysis to the first serves that landed in the service box according to the following ball–location combinations (8): flat and topspin serves down the "T" and flat and slice serves into the wide side. Thus, 24 first serves and consequently 24 serve returns (forehand and backhand strokes) were retained and analyzed. The mean velocity of serves when the ball bounced in the serve box was 183.79 ± 15.25 km·h$^{-1}$.

All collected data were normalized from the serve duration that was converted into percentage of average time. It allowed us to determine the temporal trajectory of serve–return

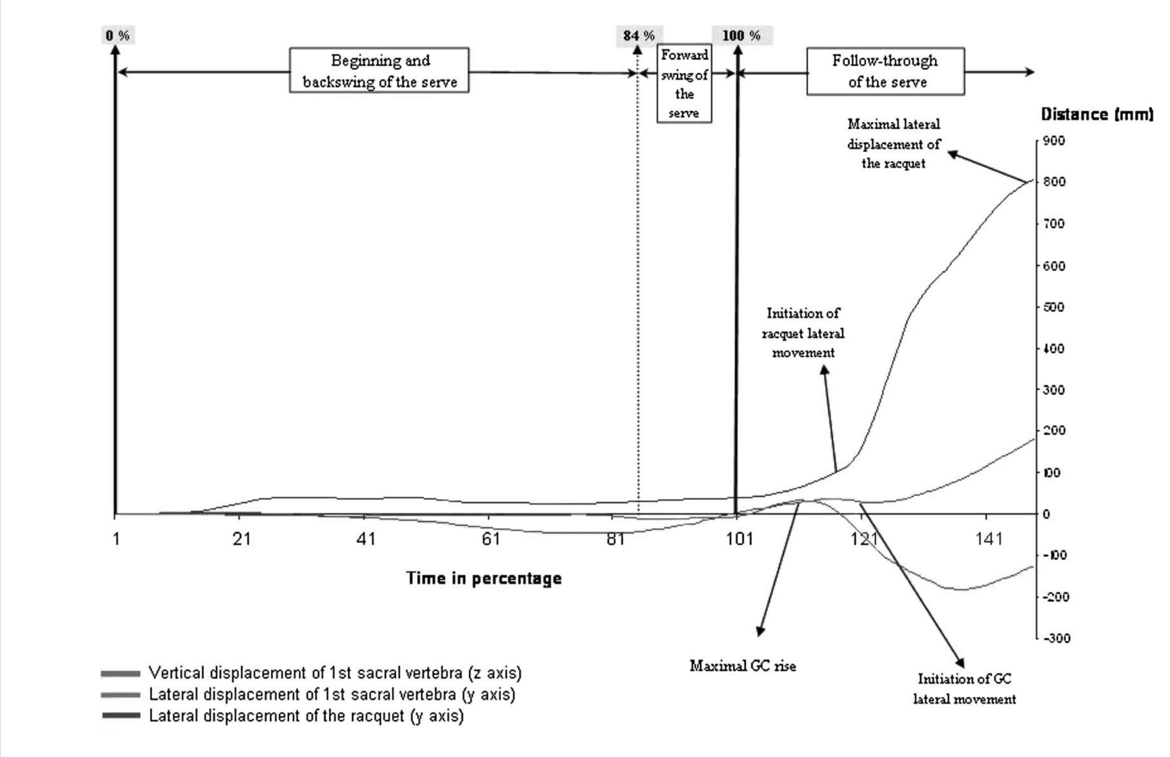

**Figure 2.** Mean spatiotemporal sequencing of backhand stroke production by the expert player.

strokes according to the duration of serves and particularly from the impact. Three phases of serve were considered for this normalization: preparation, hitting (execution), and follow-through (11). The preparatory phase begins with the elevation of the arm holding the ball (0%) and finishes with the apex of the ball trajectory (84%). It is successively followed by the hitting phase that starts with the servers' knee extension (84%) and ends at the racquet–ball contact (100%). The follow-through phase corresponds to the initial part of the ball trajectory during which the racquet moves across the server body with a gradual deceleration (148%).

### Statistical Analyses

The descriptive analysis revealed a third class of serve–returns so-called "reprogramming strokes." These motor tasks require a coherent spatiotemporal modification of the movement in a short time. In these cases, the player initiated a forehand stroke to successfully execute a backhand shot (see Figures 1–3). The independent variable was the type of serve–return strokes executed (forehand, backhand depending on the type of serves, and reprogramming strokes). A set of dependent variables enabled us to characterize the temporal trajectory of the serve–return initiation movement. These dependent variables concerned (a) the racquet displacement: the occurrence time (milliseconds) of the lateral racquet displacement, the average time of the maximal amplitude of the lateral racquet displacement, and the amplitude of the racquet displacement (mm) determined by the difference between the maximal amplitude and the initiation (characterized by the inflexion point of the trajectory) of the displacement; (b) the GC movements of the players: the occurrence time (milliseconds) of lateral and vertical GC movements and of the maximal GC rise value, the average time (milliseconds) of the GC rise value, and the amplitude of the vertical GC motion (mm) determined from the maximal rise value until the following minimal value; (c) the time of latency (milliseconds) between the onset of lateral racquet displacement and the moment of maximal GC rise that was considered as the standard reference.

All measures were analyzed using 1-way analysis of variance (ANOVA) in which the type of serves returns was considered as between-participant factors. Relevant assumptions pertaining to ANOVA, such as data normality (Shapiro–Wilk's test) and homogeneity of variances (Levene's test), were tested. Any significant main effects were sought using the Tukey Honestly Significantly Different post hoc. Statistical significance was set at $p \leq 0.05$.

## RESULTS

Figures 1–3 describe the temporal trajectory of GC movements and racquet displacement during the execution of forehand, backhand, and reprogramming serve–return strokes.

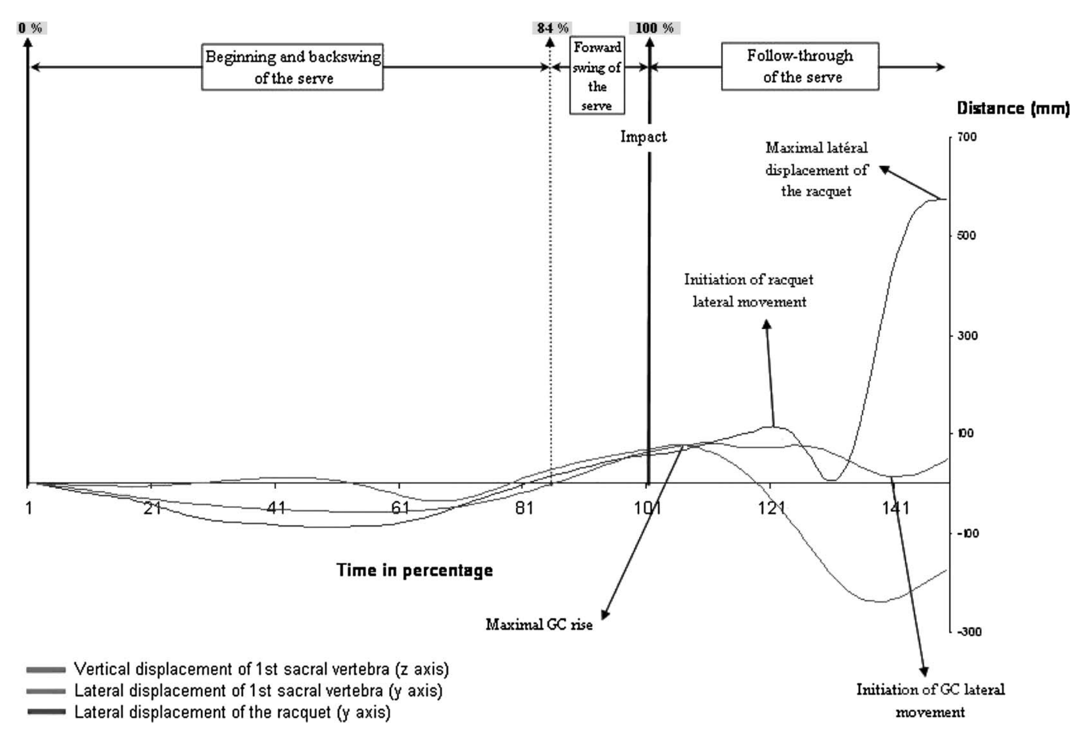

**Figure 3.** Mean spatio–temporal sequencing of reprogramming stroke production by the expert player.

A significant effect was observed for the occurrence time of the lateral racquet displacement ($F(2,21) = 3.67, p < 0.05, \omega = 0.51$), the amplitude of racquet displacement ($F(2,21) = 56.72, p < 0.001, \omega = 0.92$), and the time of latency ($F(2,21) = 10.28, p < 0.001, \omega = 0.70$). No significant effect was observed concerning the GC movements during the serve–return execution.

The initiation of the lateral racquet displacement appeared significantly later after the serve impact for the execution of reprogramming strokes (360.00 ± 24.49 milliseconds) in comparison to forehand (286.70 ± 28.39 milliseconds with $p < 0.05$) and backhands (285.00 ± 77.09 milliseconds with $p < 0.05$) shots. No significant difference was observed between forehand and backhand returns.

The amplitude of the racquet displacement is higher in forehand (1,536.92 ± 222.63 mm) than in backhand (681.20 ± 174.18 mm, $p < 0.001$) and in reprogramming (775.42 ± 22.27 mm, $p < 0.001$) strokes. No significant difference was observed between backhand and reprogramming shots.

The average latency time is longer in reprogramming strokes (297.50 ± 120.93 milliseconds) than, respectively, in forehand (132.50 ± 45.55 milliseconds with $p < 0.001$) and in backhand (156.70 ± 51.15 milliseconds with $p < 0.001$) serve returns. No significant difference was observed between forehand and backhand strokes.

## DISCUSSION

The results of the current research showed few differences in the global execution of serve returns performed by an expert player. Indeed, only some differences were observed concerning the occurrence time of the lateral racquet displacement, the average latency time, and the amplitude of the racquet displacement. As expected, this expert player uses a high consistent movement-production strategy by initiating its different serve returns with a high degree of spatiotemporal consistency. This strategy may allow a high level of spatial and temporal accuracy in the movement. The movement initiation seems to operate a fundamental role in the success of the player serve–return strokes (5,19). This movement consistency can be supported from the theory of motor programs characterized by a set of spatiotemporal invariants (16,17).

Nevertheless, in performing reprogramming strokes, the expert showed adaptive and anticipatory skills to hit the approaching ball successfully. The skilled adaptation can be interpreted from 2 paradigmatic approaches. Indeed, in the lines of the motor program concept, a player may modify its racquet movement independently of the initiation moment (16,17) or he may use prospective control mechanisms enabling the regulation of movement from the initiation of action to the moment of impact (2,3). Moreover, the lower percentage of the reprogramming strokes executed by the expert showed the relevance of his anticipation behaviors.

At last, concerning the relation between the "split step–landing" sequence and the initiation moment of the racquet swing, the expert player initiated a laterally racquet movement before the landing of the split step. The lateral GC movement coincided with the first foothold on the floor after the GC rise (Figures 1–3). The expert player begins his shots' backswing during the GC downward slope. This initiation moment when he executed reprogramming strokes was, respectively, later (i.e., after the landing of split step) than during backhand and forehand strokes (i.e., just before the landing of split step). In that case, ability to make accurate judgments based upon advance visual information may be altered by different factors such as ambiguous or deceptive movements executed by servers (9).

This case study addressed the descriptive and analytical goals of technique analysis to determine the relation between the tennis serve–return technique and the successful performance. The expert player used a predictive movement-production strategy specified by a high level of reproducibility and repeatability of the movement coupled nevertheless with an important adaptability performed during reprogramming strokes.

## PRACTICAL APPLICATIONS

Serve–return movement-production strategies and the split step–landing sequence have important implications of tennis coaches approaching. First, successful serve–return strokes depend on the specific replication of individual technique that must allow the player to develop flexible but effective movement patterns to adapt his behavior to the high time constraints and thus to manage the speed–accuracy trade-off. The more difficult the serve coming at the player, the shorter the backswing movement should be. It is advisable to train the abbreviated serve–return execution only through a backward rotation of the shoulders with a minimal arm motion and through the use of the ground reaction force and the forward rotation of the body about its own axis, combined with the use of the high velocity of the oncoming ball. Second, the timing of split step–landing sequence is crucial in the preparation for movement to a successful serve return. Although the magnitude to which a player "flexes his knees" is determined by various factors (i.e., player's morphology and physiology or anticipation skills), there is a compromise between "dipping" too low and not "dipping" low enough. Moreover, to initiate the lateral racquet movement around the summit of the split step can help to manage the speed–accuracy trade off. Thus, the coach has to manipulate the different constraints (i.e., player, task, and environment) to facilitate the learning or improvement of the key motion characteristics of the serve–return strokes. During practice sessions, the server should vary his ball toss height and the receiver should modify his position on the court. The serve–return training should not be limited to the return alone. It should encompass the server's second shot, or, even better, the receiver's second shot to verify the effectiveness and the quality of the serve–return strokes. Training sessions should also include the possible perceptive learning resulting in the understanding and deciphering of the server's game style and the spatiotemporal sequencing of his serve production. At last, these minor alterations to the movement-production strategy and the split step–landing sequence are undetectable by coaches' "eyes" who should therefore consider the use of video analysis.

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