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Editorial

Luca Santilli & Miguel Crespo

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Welcome to issue 92 of ITF Coaching & Sport Science Review, which is the first one of 2024 and marks the 32rd year of publication. In this issue, you will find a variety of articles including an introduction to the use of artificial intelligence in tennis, the study of some important body muscles for high-performance tennis, the role of self-talk routines, visualization and motivation in juniors, the severity of medical conditions of players, the factors that enable breakthroughs in tennis, an overview of listesic damage in tennis, a study on influential tennis literature, and some practical considerations on notational analysis research of the game, among others.

The ITF is happy to announce a significant decision taken by the ITF Coaches Commission (the Commission) in the context of tennis coaching certification standards. The Commission, entrusted with advising the ITF on teaching methodologies and training systems, has undertaken a commendable initiative. In its commitment to fostering excellence in tennis coaching, the Commission has embarked on updating the recommendations regarding the alignment of coaching certifications with the skill levels and ratings of tennis players.

With the dynamic evolution of the sport and advancements in coaching methodologies, periodic revisions are essential to maintain relevance and efficacy. By aligning certification levels with player competencies, coaches will gain clearer benchmarks for player development and career progression. This alignment not only benefits individual players but also enhances the overall quality of coaching across the tennis landscape.

The process of updating certification recommendations involves meticulous analysis, consultation, and collaboration with stakeholders from various spheres of the tennis community. Drawing upon insights from experienced coaches, sports scientists, and industry experts, the Commission has agreed on this decision as it is comprehensive, inclusive, and reflective of contemporary coaching paradigms.

The previous equivalence was based on the ITF's International Tennis Number (ITN) system that had been in place for a considerable period. However, with the launch of the ITF World Tennis Number (WTN), there arises a need for adaptation to reflect the contemporary landscape accurately. The transition from ITN to WTN represents a paradigm shift in how player performances are evaluated and categorized, necessitating a corresponding adjustment in coaching recommendations.

The ITF WTN system brings with it a host of benefits, including enhanced accuracy, flexibility, and inclusivity. By leveraging cutting-edge data analytics and machine learning algorithms, ITF WTN offers a more nuanced understanding of player abilities, encompassing factors beyond mere win-loss records. This holistic approach not only captures the intricacies of individual playing styles but also accounts for the dynamic nature of player development over time (ITF WTN, 2024).

Considering these advancements, it is crucial to adapt coaching certifications to ensure parity and relevance with the WTN framework. The updated proposal aims to establish clear correspondences between coaching certifications and players' playing levels, thereby enabling coaches to tailor their guidance and support according to the specific needs of each player. This alignment fosters an efficient relationship between coaches and players, facilitating more effective communication and collaboration toward shared goals.

Moreover, the equivalency with the ITF WTN system presents an opportune moment for coaches to embrace innovation and embrace new methodologies in their coaching practices. By staying abreast of the latest developments in sports science and technology, coaches can leverage data-driven insights to optimize player performance and enhance the overall coaching experience. The updated certification equivalences serve as a roadmap for coaches to navigate this transformative period with confidence and clarity (Crespo & Jabaloyes, 2020).

The approved equivalency is summarised in Table 1.

Table 1. *Equivalency between ITF Coach Certification Levels and ITF WTN player ratings (as approved by the ITF Coaches Commission).*

ITF Certification Course	ITF World Tennis Number Player Rating
Play Tennis	Work with beginner players and 10 & under children. (WTN 40 - 35 approx.)
Coaching Beginner and Intermediate Players	Work with beginner and intermediate players. (WTN 34 - 25 approx.).
Coaching Advanced Players	Work with advanced players. (WTN 24 - 16 approx.).
Coaching High-Performance Players	Work with high-performance players. (WTN 15 - 1 approx.).
The ITF WTN ratings provided for each coach certification courses are approximate as the players' rating may vary since the system is a dynamic tool that constantly evolves over time.	

Furthermore, the approved recommendations will be a valuable resource for tennis organizations, academies, and educational institutions worldwide. By harmonizing coaching standards, the ITF aims to facilitate seamless transitions for coaches operating in different regions and under diverse systems. This global approach fosters a sense of unity and coherence within the tennis coaching fraternity, transcending geographical boundaries and cultural differences.

In conclusion, the update of coaching certification recommendations by the ITF Coaches Commission signifies a pivotal moment in the evolution of tennis coaching standards. The ITF will update all its resources following this recommendation. We urge coaches to embrace this initiative wholeheartedly and actively engage in the process. Together, let us strive towards a future where every coach is empowered to unlock the full potential of every player, enriching the sport of tennis and inspiring generations to come.

As part of its Development strategy, the ITF has launched the ITF National Association (NA) Survey which asks all ITF member nations to provide their latest insight on their national tennis landscape and delivery of activities. Their contribution is an important process for the ITF to understand the latest state of tennis around the world and provides a snapshot of the health of our sport. The information shared forms the basis for the insight that has already been published beforehand within the ITF Global Tennis Reports (ITF, 2019; 2021).

This updated edition of the NA Survey sits as a service within the ITF Academy, the ITF's online education platform. It has been developed to provide a more efficient and simpler completion of the Survey for nations than with the previous editions. This platform will make the NAs' contribution of information more manageable, reflective, and easier to share.

The ITF appreciates the contribution of all National Associations in completing the NA Survey. The outputs will provide beneficial tools to assist all NAs in continually growing the sport of tennis from the grassroots right through to the highest levels in their countries. Importantly, the ITF will support the National Association's development of tennis by analysing the data provided.

The insight that is provided fundamentally allows the ITF to understand the global landscape of tennis more accurately and directly from all the member National Associations. Once analysed, the data on total players, coaches, clubs, and courts will be published in the next edition of the ITF Global Tennis Report. This data, as it has in 2019 and 2021 when published in the Global Tennis Reports, has supported the implementation of the ITF strategy ITF2024 and will continue to act as an up-to-date insight tool for future strategic development and to support the growth of tennis worldwide. Throughout the Survey, several different sections request information. This information will be shared internally with the respective ITF department to support their activities with all member nations.

National Associations should provide the most recent and latest data available across the different questions included within the Survey. In most cases, this will be data from 2023. In the instance where data from 2024 is available, this is accepted. If the most recent accurate and reliable data is available before 2023, then this will also be accepted. Data sources should be provided where applicable within the Survey.

For some National Associations, accessing accurate, valid, and reliable data first-hand (primary data) from their databases remains challenging. Consequently, when completing the NA Survey, we request you to specify what data sources have been sourced to complete specific questions – most importantly under the sections "1. Players", "2. Tennis Venues & Access" and "3. Delivery of Tennis".

Data sources may include secondary sources such as commercial data agencies and data from governments or sports ministries. Where a NA is unable to use primary or secondary data sources, an estimate can be provided. A data source and date must be provided for these questions. Where possible, NAs are also asked to provide a hyperlink to the specific source or an uploaded file of the source, multiple documents or links can be uploaded for each question.

Accurate information and insight from nations not only inform the global picture of tennis to support future ITF strategies moreover, it also provide specific national information that can support targeted action plans and context for possible resourcing to countries and programmes across different projects and activities.

The results of this ITF NA Survey will be used in a variety of ways. The data may lead to a better understanding of our knowledge about the international tennis ecosystem. It will assist in the delivery of ITF development assistance to member nations, it will help nations to know more about tennis in other nations, and it will be shared with all the participants. We very much look forward to the NAs' feedback and contribution to the updated NA Survey.

We hope that you have found this editorial article useful. It is intended to present some of the activities that the ITF is implementing to develop tennis worldwide.

We would also like to encourage new submissions to the ITF CSSR through the new platform. Finally, we would like to thank all the authors for their contributions, as well as all of those who sent in proposals. Full guidelines for acceptance and publication of articles can be found on the most recent issue page of the ITF Academy. We hope that you enjoy reading this last edition of the ITF Coaching and Sport Science Review.

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RECOMMENDED ITF TENNIS ACADEMY CONTENT (CLICK BELOW)

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7 important upper body muscles for high performance tennis players

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ABSTRACT

This article focuses specifically on the training of key, yet sometimes overlooked by amateur players, muscles and muscle groups that play a major role in both injury prevention and performance enhancement. We can learn from many high performance and professional tennis players and coaches who have adopted these important upper body exercises. The purpose of the selected muscles is to assist in stabilizing a specific joint and additionally allow these joints their proper range of motion. This information is important for players as well as coaches in helping to their players obtain optimal tennis performance. Although many muscles and movement patterns could be addressed, the specific focus of this article is on those often characterized as secondary muscles of the upper body.

Key words: tennis, muscle groups, optimal performance, injury prevention.

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INTRODUCTION

This article provides a slightly different perspective than most in discussing the development of a strength training program for tennis athletes. We are fully aware of the important role Olympic lifts, previously highlighted sport specific movements and multi-joint exercises can and do play in preparing tennis athletes for proper performance enhancement as well as injury prevention (Ličen, et al, 2022; Roetert et al, 2009a; Roetert et al, 2009b; Reid et al, 2007). In fact, based on the specificity principle of training, training programs should be both physiologically and mechanically specific to the demands of tennis (Colomar et al, 2023; Baiget et al, 2019; Martin & Prioux, 2011). However, in addition to training the major muscle groups, we would also like to draw your attention to seven often less discussed muscles/muscle groups that might not be quite as obvious but should certainly not be overlooked. For the purpose of this article, we are specifically focusing on the upper body, especially since musculoskeletal adaptations in the dominant upper extremity have been reported for range of motion, strength, and scapular biomechanics (Ellenbecker, et al, 2022). The muscle/muscle groups highlighted are not the only ones that could have been selected, but they certainly qualify for our "top 7" list, particularly related to performance and injury prevention training. The functionality of each of these muscles is described in further detail throughout the text in this article.

1. Supraspinatus
2. Infraspinatus
3. Teres Minor
4. Subscapularis
5. Serratus Anterior
6. Trapezius (lower)
7. Brachioradialis

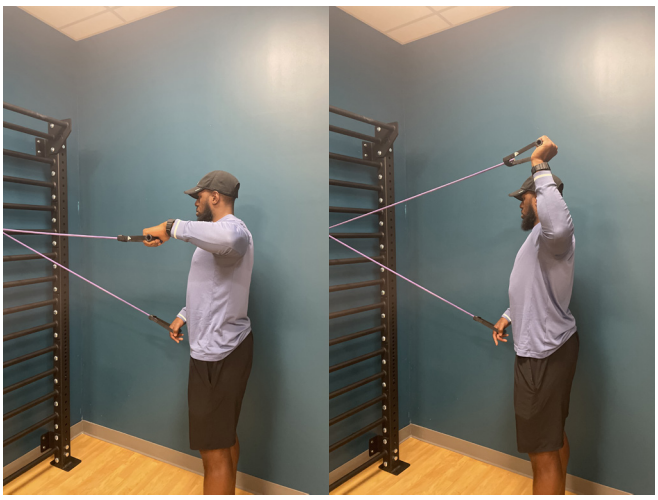
PROTECTING THE BALL AND SOCKET

As is evident from both playing and watching matches, tennis is a dynamic sport that requires rapid, powerful and repeated muscle contractions. The shoulder is one of the most versatile joints of the human body based on the anatomy as well as function of the ball and socket structure. Stabilizing and protecting this ball and socket and avoiding muscle imbalances are some of the primary functions of the muscles surrounding this joint (Ellenbecker et al, 2014). Therefore, the first four muscles were an easy choice specific to tennis players as they make up the rotator cuff.

The supraspinatus is a relatively small muscle of the upper back that abducts the arm at the shoulder and also stabilizes the humerus relative to the glenoid. The main function of the infraspinatus is to externally rotate the humerus and to stabilize the shoulder (glenohumeral) joint. The primary function of the teres minor is to exert a controlling influence on the action of the deltoid, preventing the humeral head from sliding upward as the arm is abducted. It also functions to rotate the humerus laterally and like the infraspinatus is active eccentrically to decelerate the upper extremity during the follow-through phase of the throwing or serving motion. The subscapularis helps protect the front of the shoulder joint by preventing displacement of the head of the humerus. It rotates the head of the humerus medially (internal rotation) and adducts it and when the arm is raised, it draws the humerus forward and downward as a stabilizing force.

RECOMMENDED EXERCISES

Exercise #1 - 90/90 External and Internal Rotation with Abduction



Tennis Focus

This exercise requires good shoulder stability and helps strengthen the muscles required to decelerate the arm following ball contact while serving. The movement pattern therefore focuses on the external rotators, which allow the muscles to act eccentrically. In addition, these muscles act concentrically during the loading (cocking) phase of the serve. These "decelerators" are often poorly trained by most tennis players in our experience.

Execution

Using elastic tubing equipment, attach the tubing at approximately shoulder height. Stand erect, feet shoulder-width apart, facing the tubing attachment. Grasp the resistance tubing at shoulder height with a 90-degree angle at the shoulder and 90-degree angle at the elbow. This is the starting position. Slowly externally rotate the shoulder against the resistance. The forearm starts parallel to the floor and is perpendicular to the floor at the top of the movement (external rotation at the shoulder). Hold near the end range of motion for one to two seconds. Slowly return to the starting position and repeat for 10 to 12 repetitions. Then perform the same movement with the opposite arm if you have time. It is most important to train the dominant (serving) arm for this exercise if time is limited.

Exercise #2 - Elbow-to-Hip Scapular Retraction

Tennis Focus

This exercise is focused on the muscles that are involved in maintaining good scapular position. This is particularly important for tennis players as many have weaker than required scapula-stabilizing musculature. Strengthening these muscles helps to stabilize the scapula, therefore providing for better posture and more efficient strokes. Thereby, they aid in the prevention of injury and resulting in greater power production.

Execution

Stand erect with feet shoulder-width apart and knees slightly bent, with a 90-degree angle at the shoulders and a 90-degree angle at the elbows. This is the starting positon. Slowly lower the elbows toward the hips in a controlled manner by contracting the lower trapezius and rhomboids in the upper back and cueing the shoulder blades to retract and shift down ("pinching of the scapulae"). Hold at the bottom of the movement for two to four seconds. Slowly raise the arms to the starting position.

PUSHING AND PULLING FOR SUCCESS

In addition to training the rotator cuff muscles to balance strength in a tennis player's shoulder, exercises to strengthen the muscles surrounding the scapula (should blade) are very important. The scapular stabilizers work hard, both concentrically (shortening) and eccentrically (lengthening), particularly during the groundstrokes, serves and overheads. Research has indicated that many tennis players have weaker than required scapular stabilizers (Kovacs et al, 2016). Therefore, we selected two exercises that will help in the prevention of injuries to the shoulder and upper extremity in general and allow for more efficient stroke mechanics resulting in safely creating greater power production of the tennis strokes.

The serratus anterior acts to pull the scapula forward around the thorax. As it protracts, it also stabilizes the scapula and plays an important role in its upward rotation, such as when lifting a weight overhead. The lower trapezius muscle participates in the movement of the scapula in the opposite direction of the serratus anterior by pulling and rotating the scapulae medially, essentially holding the scapulae into the thorax wall (retraction). Protraction and retraction are opposite anterior-posterior movements of the scapula. Protraction of the scapula occurs when the shoulder is moved forward, as when pushing against something or hitting a forehand. Retraction is the opposite motion, with the scapula being pulled posteriorly and medially, toward the vertebral column, such as pulling something or hitting a one-handed backhand.

RECOMMENDED EXERCISES

Exercise #1 – Shoulder punches

Tennis Focus – This exercise develops the serratus anterior which is an important scapular stabilizer. A relatively low resistance level and high amount of repetitions are recommended to train the endurance component of these muscles to match the repetitive nature of tennis.

Execution – Lie on your back with your shoulder flexed to 90 degrees and elbow straight while holding a medicine ball. Keeping your elbow straight, raise your hand toward the ceiling as far as you can. Slowly return to the starting position. If executed properly, your hand position will move about six inches up and down. We suggest starting with a 2-3lbs ball and progress appropriately.

Exercise #2 – Kneeling Lat. Pull-Down

Tennis Focus – The posterior aspect of the shoulder is a major contributor to decelerating the arm after a tennis stroke (particularly related to the forehand and serve). Retraction of the shoulder blades helps strengthen the scapular muscles. The largest and most powerful muscles of the back (i.e. Trapezius, Latissimus Dorsi) are included in this exercise. However, don't forget the Rhomboids (Major and Minor) in protecting the scapulae.

Execution – Kneel on a mat, facing a cable machine. Grab the bar with your hands slightly wide than shoulder-width apart, palms facing out. Establish a stable core and activate the gluteal muscles. Pull the bar down in front of your head to approximately the level of the sternum (breastbone). Focus on squeezing the shoulder blades together. Slowly return to the starting position and repeat.

FOREARM

The brachioradialis is a muscle of the forearm that flexes the elbow and also rotates the forearm. It is also capable of both pronation and supination, depending on the position of the forearm. The main purpose of the brachioradialis is to flex the elbow along with the biceps and brachialis muscles. When the forearm is pronated, the brachioradialis tends to supinate as it flexes the elbow. In a supinated position, it typically also pronates as it flexes the elbow. This also assists the biceps brachii and stabilizes the elbow. An additional benefit is that, when properly trained, the strength and stability in this muscle can also assist in grip function which is important for tennis players of all levels.

RECOMMENDED EXERCISES

Exercise #1 – Forearm Pronation/Supination

Tennis Focus

Although most people combine pronation and supination actions as a unit, we will hereby focus specifically on the supination activity since it provides a greater involvement of the brachioradialis. Developing appropriate strength and endurance in the forearm muscles helps with shot execution and also reduces risk of wrist and shoulder injuries. Forearm supination helps involve the wrists, particularly in hitting a two-handed backhand. This action allows for greater spin and the potential to create angles that would not be possible without this movement. Developing strength in the forearm is also beneficial to improve performance of both forehand and backhand volleys and helps to also prevent tennis elbow.

Execution

Sit or kneel beside a weight bench. Position your forearm and elbow on the bench. Establish a stable and rigid shoulder position. Grasp a hammer or other piece of equipment with a weighted head in one hand. Begin with the hammer head pointed to the ceiling. Slowly and with control rotate your forearm. Take two to four seconds to rotate your forearm to avoid using momentum. If the hammer is in your right hand, your thumb will move to the right as you rotate your forearm. At the end of the movement, hold the position for two seconds and then slowly return to the starting position. After performing a set with one arm, switch arms and perform the same movement pattern on the other arm.

Exercise #2 - Hammer Curl

Tennis Focus

Tennis requires you to handle a racket for hours during a match, therefore sufficient grip and forearm strength and muscular endurance are important. The muscles developed in the arm curl exercise play a role in the follow-through of both forehand and backhand groundstrokes. On the forehand, the deceleration of the arm during the backswing is partially aided by the contractions of the biceps, brachialis and brachioradialis. This action supports the decelerators of the shoulder. During the backswing and follow-through on the backhand groundstroke, the biceps is recruited to help support other muscles of the shoulder and upper back.

Execution

Stand with a stable lower body position. Hold a dumbbell in each hand, arms extended by your sides with your core muscles contracted. Lift one dumbbell toward your shoulder in a straight path by bending the elbow to approximately 90 degrees while maintaining a stable core and lower body position. Pause at the end of the movement and slowly lower the dumbbell to the starting position. Repeat with the other arm. Alternate arms for 10 to 12 repetitions.

SUMMARY

Training tennis athletes requires a combination of movements for the development of strength, power and endurance to improve acceleration and deceleration in various planes of motion. The purpose of this article was to highlight some of the sometimes overlooked, yet critically important upper body muscles that play a complementary role in the major movements of successful tennis players with the purpose of injury prevention as well as performance enhancement. Although larger muscle groups are critical for success, these complementary muscles should be considered for tennis players and their coaches at all levels of performance. The goal is to highlight the need to improve the training of some of these auxiliary exercises that should be incorporated into a tennis players training program in addition to the more commonly utilized exercises that are focused for strength, power and muscular endurance.

CONFLICT OF INTEREST AND FUNDING

The authors declare that they do not have any conflict of interest and not receive any funding to conduct the research.

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A routine combining motivational self-talk and mental imagery improves service performance

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ABSTRACT

The aim of this study was to test the effects on the performance of experienced tennis players of a service pre-performance routine consisting of internal motivational discourse combined with mental imagery centred on the trajectory of the ball and the target zone to be reached in the service box. Twenty-seven male players (M = 17.5 years) from the second series (ranked between 5/6 and 3/6), who had been playing tennis for more than 10 years, volunteered to take part in this experiment. The participants were divided into 3 groups (control, discourse, and discourse + imagery) and carried out 3 phases: Pre-test (20 serves in playing condition), Acquisition: 16 sessions (warm-up + 20 serves + super tie-break), Post-test (20 serves in playing condition). The percentage of success, speed and efficiency of the serves were measured at the Pre- and Post-tests and served as dependent variables for statistical analyses (repeated measures ANOVAS). The results of this study show a further improvement in serve performance when internal motivational discourse is combined with mental imagery. We recommend that experienced tennis coaches and players use internal self-talk as well as imagery in their pre-serve performance routines.

Key words: tennis, service, mental simulation, internal discourse.

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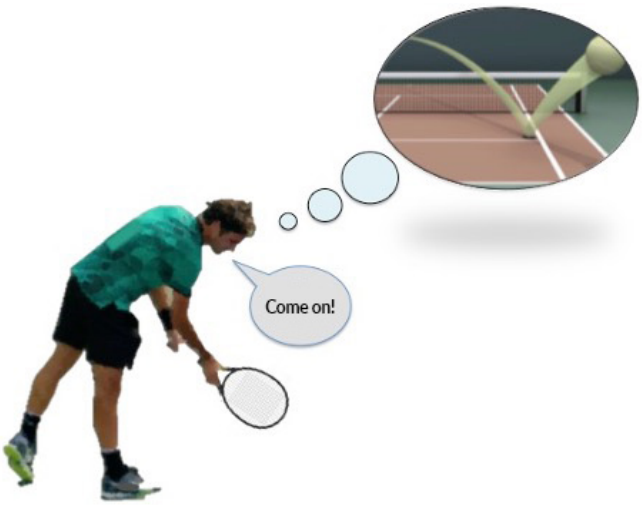
INTRODUCTION

Coaches and athletes recognise the value of using mental strategies, such as internal discourse and mental imagery, to improve performance in racquet sports (Cece et al., 2020; Crespo, Reid & Quinn, 2006; Robin et al., 2023). According to Latinjak et al. (2019), internal discourse refers to externalized or internalized verbalizations that tennis players address to themselves. These verbalisations can be spontaneous (uncontrolled) or strategic (linked to a predetermined objective) as mentioned by Van Raalte et al. (2016). Strategic internal discourse is a deliberate mental technique frequently used by practitioners to optimise performance by means of its cognitive function, which is generally technique-oriented (e.g., "Straighten your arm", "Bend your legs", "I have to finish my gesture") and which will help guide the execution of movements in beginners (Boudreault et al., 2016). Internal discourse can also be used to regulate the emotions of more experienced players through its motivational function (Fristch et al., 2020). For example, internal motivational discourse can be used to pro-actively or reactively regulate emotions (e.g., "Enjoy playing"), motivation ("Go ahead", "You can beat him") or effort ("I'm going to keep up", "I'm going to win the next set"), which is why it is so useful in training and especially in competition (Grammatika et al., 2008).

Other authors such as Robin and Dominique (2022) have recently shown that tennis players also frequently use other strategies such as mental imagery, which consists of mentally simulating a motor action, such as serving, to improve performance. This mental technique can be integrated into motor performance routines (Dominique et al., 2021; Le Scanff, 1999) to shift players' attention to elements other



than movement technique, such as the trajectory of the ball (Guillot et al., 2013), and make it easier to trigger movements under conditions that are as standardised as possible, hence its usefulness for serving (Dominique, 2005). Numerous studies have shown the positive effects of mental imagery as a complement to the actual execution of motor actions in racket sports (Cece et al., 2020) and particularly in tennis (Robin & Dominique, 2022). In addition, other authors have suggested that there would be additional beneficial effects if mental imagery were combined with other mental strategies such as internal self-talk (Dohme et al., 2020; Mamassis & Doganis, 2004) and if they were integrated into pre-performance routines constructed during training and used in competition (Robin et al., 2023).

The aim of this study was to evaluate the potentially beneficial effects of a service pre-performance routine consisting of internal motivational discourse combined with mental imagery (based on the trajectory and target to be reached) on the performance of first service balls in match situations. We began by hypothesising that the players who benefited from the internal motivational discourse would perform better than the players in the control group. Secondly, even better performance should be obtained by players using the combination of internal discourse and mental imagery before serving.

METHOD

27 male tennis players (Mage = 17.5 ± 1.6 years), second series (French rankings between 5/6 and 3/6 corresponding to the US 5.0 ranking), volunteered to take part in this experiment. They had been playing tennis for more than 10 years and regularly took part in regional competitions in Réunion and national competitions in mainland France. The participants were randomly divided into 3 experimental groups (control, self-talk, and self-talk + imagery). All the players completed the movement imagery questionnaire (MIQ-3f, Robin et al., 2020) to check that none of them had difficulty with mental imagery. The MIQ-3f differentiates imagery abilities for the internal visual, external visual and proprioceptive modalities. It consists of 12 items (4 per type of imagery), involving the actual execution of simple movements of the arms, legs and whole body, followed by mental imagery of these same movements. The internal visual, external visual and proprioceptive imagery capacities of each item, performed and then mentally simulated, were assessed using 7-point Likert scales (ranging from 1 "very difficult to imagine or feel" to 7 "very easy to imagine or feel"). The experiment, approved by the ethics committee of the ACTES laboratory at the Université des Antilles, was conducted in accordance with the latest version of the Declaration of Helsinki.

PROCEDURE

After the consent form had been signed by the adult players, or their legal representatives in the case of minors, the participants completed the MIQ-3f questionnaire (Robin et al., 2020), then took part in 3 experimental phases (see Figure 1) on outdoor hard courts at the "Team Run Elite" of the Tennis Club Dyonisien de la Réunion.

The first phase, or Pre-Test, consisted of all the tennis players performing 20 serves in match conditions (super tie-break) with new balls (Head Tour XT). The second, or Acquisition phase, consisted of 16 sessions, with 2 sessions per week. Each session, lasting 40-45 minutes, consisted of a standardised 20-minute warm-up followed by 20 serves under match conditions with new balls lasting around 20 minutes. The players in the control group were instructed to perform the serves only physically. Participants in the discourse group were asked to use a positive motivational phrase (e.g., "I'm going to succeed", "Go ahead", "You can do it", "Serve well and win the point") before completing each serve. Finally, the players in the self-talk + imagery group were asked to imagine themselves using an external visual modality (i.e., seeing themselves in the third person as if they were being filmed with a camera) making a successful serve by visualising the trajectory of the ball and the target zone they wanted to reach in the opponent's service box (for a similar procedure, see Dominique et al., 2021), while using the motivational self-talk. The last phase, or Post-test, was like the Pre-test and was also carried out with new balls (Head Tour XT).

The participants' performances during the pre- and post-tests were filmed with two cameras (Canon HD Legria HF G25, Tokyo, Japan). The two cameras were positioned respectively on the right and left of the baseline, 4 m from the doubles touchline (for a similar procedure see Robin et al., 2022). The percentage of success (i.e. bounce of the service ball in the target square), the speed of the service ball (measured with an SR 3600 radar gun) and the efficiency of the services (scores ranging from "0" for a ball in the net to "5" for an ace, assessed by two BEES1 and DESJEPS Tennis experts) were

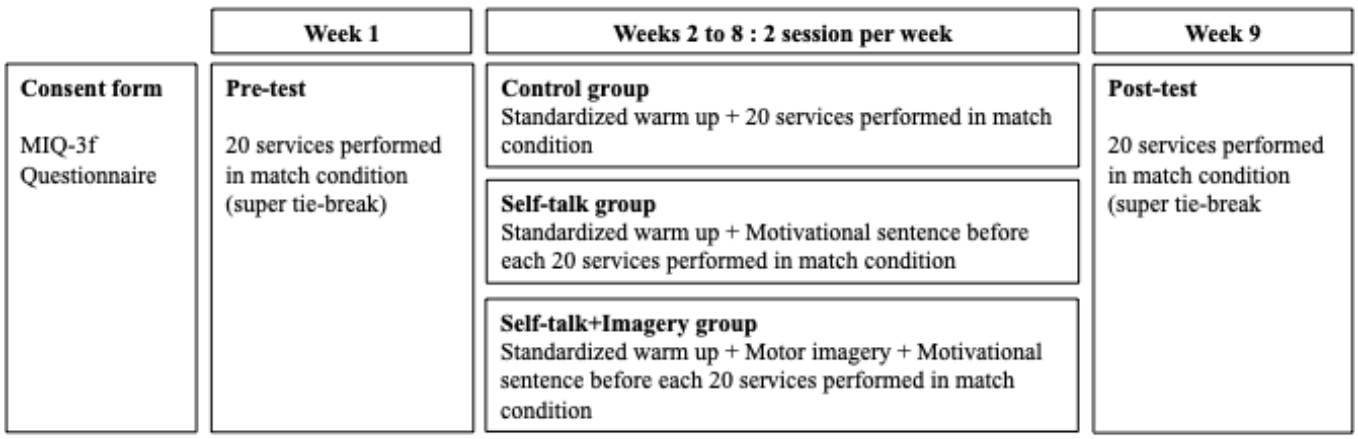


Figure 1. *Experimental sequence.*

measured in the Pre- and Post-tests. The experts carried out the assessments independently and then met to reach a consensus on the rare cases of non-similarity (only 2% of the efficiency scores of the services concerned). After checking their normality (Kolmogorov-Smirnov test), the dependent variables were subjected to repeated-measures ANOVAS. Post-hoc analyses were performed using the Newman-Keuls test and an alpha threshold of .05 was used.

RESULTS

None of the players, and in particular the participants in the self-talk + imagery group, had any difficulty with mental imagery (all mean scores on the MIQ-3f were above 3.7/7; Robin & Blandin, 2021).

The ANOVA carried out on the speeds of the first service balls showed no significant difference between the performances of the control (M = 154.5 km/h), self-talk (M = 156.3 km/h) and self-talk + imagery (M = 157.1 km/h) groups between pre-test and post-test and between the experimental groups at post-test (all p > .05).

The statistical analysis carried out on the service success percentages showed that only the self-talk and self-talk + imagery groups improved their first serve success percentages, by 8% and 12% respectively, between the pre-test and the post-test (all p < .05) whereas those of the players in the control group were not statistically different between the tests (45% in the pre-test and 48% in the post-test as shown in Figure 2). In addition, players in the self-talk + imagery group obtained a better percentage of success (M = 59%) than participants in the self-talk group (M = 54%) and those in the control group (M = 48%), at the post-test (all p < .05).

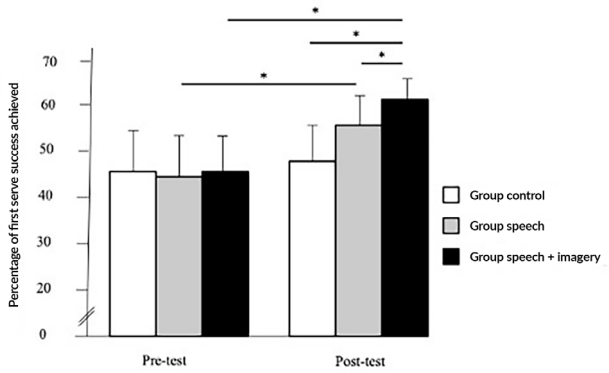


Figure 2. *Percentage of first serve success achieved by players in the experimental groups (control, self-talk, self-talk + imagery), in the pre-test and post-test (* p < .05).*

The analysis carried out on the effectiveness scores of the services revealed that only the self-talk and self-talk + imagery groups significantly improved their performance (all p < .05) between the pre-test (M = 2.23; M = 2.24) and the post-test (M = 2.71; M = 2.73 respectively), whereas the average effectiveness score of the players in the control group remained stable (p > .05) as shown in Figure 3. In addition, players in the self-talk and self-talk + imagery groups obtained better scores (M = 2.71 and M = 2.73 respectively) than those in the control group (M = 1.98), at Post-test (all p < .05).

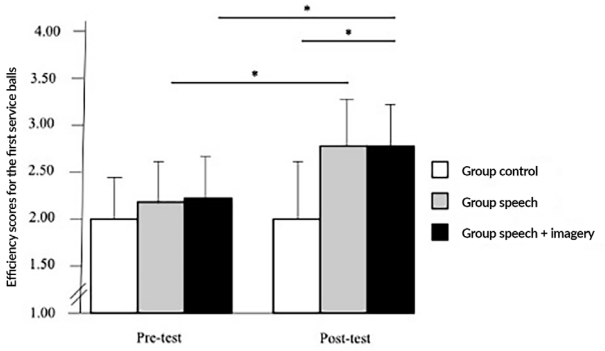


Figure 3. *Efficiency scores for the first service balls, calculated on the basis of pre-test and post-test performance, for the experimental groups (control, self-talk, self-talk + imagery) (* p < .05).*

DISCUSSION

The aim of this study was to evaluate the effects of a service routine involving a combination of internal motivational discourse and mental imagery on the first serve performance of experienced tennis players.

Initially, the results of this study show a beneficial effect of positive motivational internal discourse on the percentage of successful first service balls, whereas that of players in the control group remained stable. These results, which validate our first hypothesis, also confirm the results of previous studies that have shown beneficial effects of internal discourse on sports performance (Boudreault et al., 2016; Theodorakis et al., 2000), particularly in tennis (Fristch et al., 2020; Robin et al., 2022). As mentioned by Landin and Hebert (1999), we could envisage that positive motivational internal discourse would increase players' self-confidence, which would enable them to increase their percentage of successful first service balls. Although the use of internal discourse with a positive valence is recommended (Zourbanos et al., 2006), negative discourse could be beneficial to the performance of certain players, at certain moments in the match, because it would allow them to release tension (Van Raalte et al., 2000). We therefore recommend that coaches and trainers work with the players to determine which expressions should be used as internal discourse.

Secondly, the results of our experiment show that the tennis players who used motivational internal discourse combined with mental imagery not only had higher service efficiency scores than the players in the control group, but also obtained a higher percentage of successful first service balls than the participants in the control group and the motivational internal discourse group. These results, which validate our second hypothesis, confirm the value of combining mental techniques in tennis (Dohme et al., 2019; Robin et al., 2021; 2022; 2023), particularly when they are integrated into pre-performance routines (Dominique et al., 2021). As mentioned by Hardy (2006), it is possible that internal motivational discourse, used in combination with mental imagery, would increase tennis players' self-confidence. In addition, we could also envisage that the positive phrases used by players accompanying the simulation of a good serve, in their heads, would give them an advantage during matches by increasing their feeling of self-efficacy (Chang et al., 2014). Further research will soon be carried out in our laboratory to test this hypothesis.

It is important to stress that this study is not without its limitations. In fact, the pre- and post-tests were carried out under training conditions and not in an official match; this is why further research is needed to test the effects of imagery and/or internal self-talk in a real competition situation. In addition, the fact that the speeds of the first balls measured were relatively low (around 150 km/h) may lead us to question the degree of accuracy of the radar gun, which was nevertheless one kilometre per hour, but also the degree of expertise of the participants in this study. It would therefore be appropriate to carry out similar research with players on professional circuits.

CONCLUSION

The results of this experiment, carried out with experienced players, show a further improvement in first serve performance when motivational internal self-talk is combined with motor imagery. We recommend that experienced tennis coaches and players use internal discourse combined with mental imagery in their pre-performance routines on the serve, first in training and then in matches. To optimise the effects of these techniques, we suggest on the one hand developing the players' imagery skills by gradually integrating mental imagery into training sessions and on the other hand determining individually the expressions to be used as internal discourse. From a research perspective, we suggest directing attention towards the players' preferred imagery modalities (i.e. internal visual, external visual or kinaesthetic, or even a combination of several of them) that would be used during mental simulations of the services.

CONFLICT OF INTEREST AND FINANCING

We have no conflicts of interest to declare and this study was not funded.

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Important performance characteristics at Wimbledon: Implications for coaches

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Key words: Successful performance; Elite tennis; Wimbledon; Performance analysis.

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INTRODUCTION

My research has sought to address the lack of performance analysis investigations into elite grass court tennis. In addition to introducing and validating a new, coach-friendly data analysis method, designed to encourage coaches to embrace performance analysis (Fitzpatrick et al., 2018), our research has advanced knowledge on the important aspects of elite grass court tennis match-play, and provided new insight into how matches are won at Wimbledon. This evidence-informed article summarises the key findings and then, crucially, considers the practical applications from a coaching perspective.

KEY FINDINGS

Longitudinal analysis of men's and women's matches at Wimbledon showed that although the characteristics of match-play evolved between 1992 and 2017, short points (points of between 0 and 4 shots) remained the most important aspect throughout. Informed by coaches' knowledge of the sport, we then defined 'closely contested' and 'one-sided' tennis matches, with analysis revealing that short points remain highly important in both closely contested and one-sided matches (Fitzpatrick et al., 2024). With only 3 weeks typically separating Roland Garros and Wimbledon, a comparison of the two Grand Slams provided important context to inform players' training strategies during the crucial, but time-pressured, clay-to-grass surface transition (Fitzpatrick et al., 2019). Interestingly, despite the slower nature of clay courts, short points prevailed again, as the most important aspect of match-play, on both surfaces, with players who won more short points than their opponent winning the match in 85-92% of cases (Fitzpatrick et al., 2019; see Table 1). Note that a higher PWOL value indicates a stronger positive association with match outcome (i.e., with winning matches).

Researchers and coaches have consistently acknowledged the serve as the most important shot in tennis, with some also highlighting the vital nature of the return (Ruder, 2019). 'Serve plus one' strategies (where a player executes a serve and then aims to put the ball away with their next shot) are also considered crucial components of a players' arsenal (O'Shannessy, 2019a), and therefore feature heavily in practice sessions. These practitioner observations along with the clear importance of short points led us to investigate points of 0-4 shot rally length in more depth. Our analysis reaffirmed the importance of effective serving and returning strategies for winning matches at Wimbledon, but also indicated that serve plus one strategies (i.e., points of 3 shots) do not differentiate winning and losing players (Fitzpatrick et al., 2021; see Table 2), which could cast doubt over their current prioritisation within training. Note that a PWOL value close to 50% indicates no association with match outcome.

Tactical analysis of Hawk-Eye ball-tracking data provided insight into the most common and most effective serving and returning strategies for men and women at Wimbledon (Fitzpatrick et al., 2023). Perhaps unsurprisingly, serves and returns that landed in more lateral areas of the court (i.e., closer to the sidelines) were more successful than those that landed more centrally, and winning players executed both serves and returns more accurately to lateral areas than losing players.

IMPLICATIONS FOR COACHES

Findings revealed that points of 0-4 shot rally length (i.e., short points) was the most important performance characteristic in terms of winning matches at Wimbledon, irrespective of sex (male/female), time (from 1992 to 2017) and match closeness (closely contested/one-sided) (Fitzpatrick et al., 2024). Coaches should be aware of the prevalence and importance of short points, and design players' training accordingly. Guided by Pinder et al.'s (2011) representative learning design framework, coaches should ensure that short rallies and point-ending strategies are fundamental aspects of players' grass court training sessions. However, tennis strategy analyst, Craig O'Shannessy, has suggested that elite players spend around 90% of their practice time engaging in long, baseline rallies (O'Shannessy, 2019b). This type of practice develops rhythm and consistency, and should therefore not be abandoned, but the importance of providing a training environment that is representative of the performance context should not be overlooked. Our findings therefore suggest that the amount of time spent practicing long baseline rallies should be reconsidered and potentially reduced, due to the high prevalence and unconditional importance of short points (Fitzpatrick et al., 2021). Where necessary, coaches can be guided on how to design more representative baseline rallies, to ensure high levels of specificity within players' training; strategies for this are presented shortly.

Our results consistently highlighted the crucial role of serving and returning strategies at Wimbledon. According to O'Shannessy (2020), the serve and particularly the return are drastically under-practised skills, relative to their prevalence in elite match-play. Although this has not yet been investigated empirically in

Table 1. Men's and women's PWOL values (i.e., importance in terms of winning matches) for the most important performance characteristics at Roland Garros and Wimbledon (derived from Fitzpatrick et al., 2019).

Performance characteristic	Roland Garros		Wimbledon		Average PWOL
	Men's PWOL	Women's PWOL	Men's PWOL	Women's PWOL	
Points won of 0-4 rally length	89%	85%	92%	87%	88%
First serve points won	85%	83%	85%	84%	84%
Baseline points won	82%	84%	79%	90%	84%
Second serve points won	77%	76%	73%	79%	76%
Points won of 5-8 rally length	65%	68%	69%	72%	69%
Points won of 9+ rally length	66%	56%	61%	58%	60%

Table 2. Mean (± sd) number of points won of each rally length by winning and losing players of both sexes at Wimbledon, and corresponding PWOLs (i.e., importance in terms of winning matches) (derived from Fitzpatrick et al., 2021).

Rally Length	Men			Women		
	Winning players	Losing players	PWOL	Winning players	Losing players	PWOL
0 shots	4.2 ± 2.7	3.2 ± 2.4	56%	3.5 ± 2.2	2.7 ± 2.3	55%
1 shot	41.3 ± 15.5	35.0 ± 16.2	71%	18.9 ± 7.0	15.4 ± 7.5	71%
2 shots	15.1 ± 5.9	10.4 ± 5.3	77%	11.0 ± 4.3	8.1 ± 4.4	71%
3 shots	18.3 ± 7.2	18.0 ± 7.7	48%	11.0 ± 4.3	9.9 ± 4.8	54%
4 shots	10.6 ± 3.7	7.1 ± 3.7	72%	7.8 ± 3.5	5.9 ± 3.2	66%
0-4 shots (combined)	89.5 ± 25.7	73.7 ± 28.6	92%	52.3 ± 14.3	41.8 ± 16.7	87%

professional tennis, Krause et al. (2019) analysed junior players' training sessions and demonstrated that serves and returns comprise only 10% and 3% of total practice time, respectively. With our findings demonstrating that serving and returning strategies are highly influential to the outcome of matches (Fitzpatrick et al., 2021), serves and returns should undoubtedly be prioritised during grass court training. Results showed that, for male players, returns may in fact be more important than serves (Fitzpatrick et al., 2021), so it is particularly important for men's coaches to ensure that returns are afforded sufficient practice time. Additionally, players tend to practise the serve by repeatedly hitting balls from a basket, often engaging in conversation simultaneously (Meffert et al., 2018) and without a returning player present (Krause et al., 2019); it is important to address the limited representativeness of such practice designs. To more accurately represent the performance context, serves and returns should not be practised in isolation, but rather as they occur during match-play – as part of a series of strokes, beginning with a first or second serve (Krause et al., 2019). Therefore, serving practices in which players are dissuaded from talking, a returning 'opponent' is active, and the serving player is required to perform the next stroke if the return is successful, are advised.

Serve plus one strategies (i.e., 3-shot rallies) did not differentiate winning and losing players, casting doubt on previous claims that they are crucial in elite tennis. However, this finding must be considered in context; 3 shots was found to be the second most common rally length, and changing the amount of practice time afforded to serve plus one strategies could lead to players becoming less proficient at executing them. So, it would be unwise to suggest that serve plus one strategies should not be practised, but coaches could ensure specificity, affording time to the specific strategies that their player executes either more or less successfully during matches.

Serves and returns landing close to the lateral edges of the court were more successful than those landing in central zones (Fitzpatrick et al., 2023). The importance of short points, the importance of serving and returning strategies, and the success of serving and returning to lateral zones (compared to central zones) collectively indicate that success is typically attained at Wimbledon by executing attacking strategies that put the opponent under pressure early in the point. In line with these findings, coaches should design practices that elicit proactive behaviours and foster attacking strategies, such as playing on the front foot, stepping inside the baseline, taking the ball early (i.e., on the rise), and putting the opponent under positional and/or time pressure.

Newell's constraints-led model is an effective pedagogical approach for promoting desirable emergent behaviours (Renshaw & Chow, 2019), and can therefore underpin coaches' development of such practice designs. Below are four task designs that coaches could explore, whereby constraints are manipulated to encourage functional behaviours. These suggestions are informed by our research findings and derived from tennis coaching literature.

1. Time-restricted rallies

Players rally for 60 seconds, with the aim of hitting as many strokes as possible (ideally within one rally). As players explore behavioural adaptations to achieve the goal, they learn to reduce the amount of time between strokes, and therefore hit more strokes within the time limit, by taking the ball early and executing an attacking ball trajectory. Time-constrained tasks can also improve players' capacity to play at a high tempo while maintaining consistency, a vital skill in tennis (Antoun, 2007). Informed by the finding that short points are closely associated with success, this task will encourage players to put their opponent under time pressure early in the point. In time, this task could also progress to become direction-based (i.e., cross-court or down-the-line), to be more representative of match-play scenarios.

2. Adapted playing space

Use masking tape or markers to create a line 10 cm behind the server's baseline, demarcating the effective playing space that players must stay within. Under this adaptation, incoming balls that land near the baseline must be taken on the rise to satisfy the task demands. Over time, players learn that this imposes time pressure on the opponent. During points-based activities, this manipulation ensures that players do not retreat after serving, in turn promoting active consideration of an appropriate serving strategy, as an added benefit. This task is informed by the importance of serving strategies, and the finding that winning players hit a higher proportion of their serves to lateral areas of the service box than losing players. A similar adaptation could be applied for the returning player, to encourage increased focus on returning strategies.

3. Two steps forward

During return-focused tasks, ask players to take two steps forward after each stroke. This promotes hitting on the front foot and moving through the ball, and fosters an attacking mentality, as it is difficult to play defensively when moving forwards. With the importance of returning strategies (particularly for men), this will encourage players to attack the return, to try to prevent the server from dominating the start of the point. This manipulation can also be used during baseline rallies to improve players' forward and backward movement skills, which are typically weaker than their lateral movement skills.

4. Bonus points for creating perturbations

Coaches can award a bonus point if players miss by a small margin while attempting to create a perturbation (i.e., apply time or positional pressure) early in the point, to promote positive intent. For example, if a player serves wide to the advantage court, then moves into the court and attempts but misses (clipping the tape) an aggressive down-the-line backhand on their next stroke, they could be awarded a bonus point for controlled, positive intent. Informed by the importance of short points, this task fosters an attacking (rather than passive or defensive) approach to the first few shots of each point, by negating the psychological pressure associated with committing an error. Bonus and/or penalty points can be applied to many activities, to promote desirable behaviours or dissuade less-desirable behaviours.

Relevant verbal instruction and feedback (i.e., clear, simple statements) can be provided by coaches to supplement these manipulations (Reilly & Williams, 2003). Examples that reflect our findings include 'hit through the ball', 'take their time away' or 'strike first' to encourage proactive play (Ruder, 2019). Where possible, practice environments should also elicit the cognitions and emotions associated with competition, to better support the emergence of functional behaviours and exhibit fidelity with the performance context (McCosker et al., 2019). Coaches can aim to re-create the high-pressure environment of competition using forfeits and rewards (Stoker, 2017), or by implementing time restrictions and/or situational scoring manipulations (e.g., the player must start each game 0-30 down). As tennis is an individual sport, putting players into teams, whereby everyone's performance affects the success of the wider team may also help to simulate pressure.

For the successful implementation of practice designs, players must understand the purpose, relevance and context, to ensure they adopt an appropriate mindset (Ruder, 2019). Based on our findings, players should approach practice prepared to actively search for and create opportunities to win the point, rather than passively waiting for opportunities to arise or for their opponent to commit an error. To facilitate this mentality, coaches could ask players to verbalise their tactical intention as they perform each stroke, by calling out 'defend', 'neutral', or 'attack', for example. Self-evaluation, an important skill for athletes, has been shown to improve focus, and enhance particularly those areas within players' control, such as the serve (Taylor & Wilson, 2005). Self-assessing the effectiveness of serves and returns during training, by scoring them out of ten, based on how difficult the player perceives each stroke to be for an opponent to retrieve, could encourage exploration of different ways to execute serves and returns to increase the likelihood of creating a perturbation (i.e., putting their opponent under pressure).

Crucially, the coaching application outlined in this article is not 'one size fits all', and must be individualised. Given the array of game styles in tennis, and players' individual personalities, coaches have an inherent responsibility to know their own player's game and character well enough to determine how, and the extent to which, they should implement these recommendations (Reilly & Williams, 2003). In this way, the tactical strategies of an individual player should maximise their strengths, while limiting the opportunities for opponents to exploit their weaknesses. (Antoun, 2007). How coaches communicate the context of findings and associated adaptations is also important (Jones et al., 2004). For example, with a male player whose weapon is their powerful serve, a coach could highlight the strengths of this game style on grass courts, based on the critical importance of serving and the importance of first serve speed and aces uncovered in our research, to instil confidence and self-belief (Wilkins & McBrien, 2018). However, for a player whose strengths are movement and shot consistency, the coach expressing that their game style is not ideal for grass courts (as long points are not important for winning matches at Wimbledon) is unlikely to be beneficial. So, clearly, coaches must consider players' gamestyles and personalities before deciding how best to design sessions and explain adaptations to them.

SUMMARY

- Based on our research findings, coaches should design grass court practices that elicit proactive behaviours and foster attacking strategies (e.g. playing on the front foot, taking the ball early, and putting the opponent under positional and/or time pressure).
- To reflect match-play, coaches should develop representative and specific serve, return and serve plus one based practice, and consider the amount of time players spend engaging in long, baseline rallies.
- The four constraints-led task designs presented here demonstrate how coaches can apply the current findings, complemented by appropriate instruction and feedback, to ensure representative practice.
- Coaches should tailor the implementation of such task designs, based on individual players' game styles and characters.

CONFLICT OF INTEREST AND FUNDING

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Severity of medical conditions of top-level male tennis players: implication for prevention

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ABSTRACT

Although tennis is one of the most popular sports practiced worldwide by millions of players, there are no data on the time necessary to return to playing after injuries or illnesses. To contribute to the discussion regarding time-loss medical conditions (TLC), a retrospective web search was conducted on the first fifty tennis players listed in the ATP ranking on February the 20th 2022, looking for TLC in a five-year period (1-1-2018 to 25-12-2022). We recorded 267 TLC 137(51%) of them occurred during tournaments and 130(49%) during training sessions. Recurrences were 31% affecting 27(54%) players. Most TLC were treated conservatively (N=256; 96%), while 11(4%) needed surgery. The median time loss of all the 267 TLC was 17 days (range 1-378). For conditions requiring surgery (n=11), the median was 61 days (range 10-367). Injuries, as opposed to illnesses, accounted for 81% of all TLC. Players and coaches should know the effects of medical conditions on the career of players and how to set-up an effective prevention program starting from early childhood. Prevention in top players should consider also playing surfaces and overall lifestyle including nutrition and sleep, together with other healthy measures such as vaccinations, especially for players traveling around the world.

Key words: epidemiology, illness, injury, return to play.

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INTRODUCTION

Tennis is one of the most popular sports practiced worldwide by millions of players at recreative and professional levels, reaching individuals of all ages and all skill levels. The metabolic demands of a tennis match are satisfied by both aerobic and anaerobic metabolisms because of the typical intermittent nature of the sets characterized by repetitive actions of short-duration and high intensity (Kovacs, 2007). Consequently, players perform hundreds of power strokes per match, looking for high ball velocities through a variety of technical movements including overhead serves, smashes, and groundstrokes. Furthermore, a tennis match can extend for hours because there is no time limit on how long players can play, although in most tournaments matches played to three sets lasts about 1.5 hours on average and are characterized by 5-10 seconds of attack and 10-20 seconds of recovery on average (Fernandez-Fernandez et al., 2009).

From all the above, tennis players are susceptible to develop a variety of injuries indexes (Dines et al., 2015) form acute traumatic, commonly occurring in the lower extremity, to chronic overuse conditions, most often manifesting themselves in the upper extremity and trunk (McCurdie et al., 2017). Pluim et al. (2006) reported a cumulative incidence ranging from 0.04 to 3.00 injuries per 1000 hours played, although the incidence of injuries in tennis varies according to age, gender, level of play, study design and definition of injury or medical condition.

There are several articles published in literature regarding the epidemiology of tennis however, there are no reports regarding time-loss and severity of medical conditions occurred during the career of top-level tennis players, including conditions not related to tennis. Thus, the aim of the present study is to contribute to the discussion regarding this aspect of the epidemiology of top tennis players analyzing the first fifty positions of the ATP ranking, to suggest implications for prevention.

METHODS AND PROCEDURES

To collect information on both injuries and illnesses, the term "medical condition" was adopted (Pluim et al., 2009). However, differently from the consensus statement on epidemiological studies of medical conditions in tennis (Pluim et al., 2009), conditions not related to tennis were also included to explore the effects of being unhealthy on the career of top players. Thus, a time-loss condition (TLC) was defined as an injury or illness that leads a player to be unable to take full part in future matches or training sessions.

The retrospective search was conducted on the first fifty tennis players listed in the ATP ranking on February the 20th 2022, looking for TLC in a five-year period from January the 1st 2018, to December the 25th 2022.

Data were collected by consulting the websites of the tournaments and searching the personal websites of the players and online sports newspapers for TLC. Searches were conducted using Google and Yahoo as web search engines typing several keywords: tennis, injury, illness, training, withdraw, and the names of the tournament and of the players variously associated with each other. When a medical condition was found, the information was checked, and the web search was deepened for the place, date, and name of player and of the tournament.

The analysis was performed on publicly available data, in accordance with the 1964 Helsinki declaration involving human participants and its later amendments or comparable ethical standards. Data were anonymized and analyzed with descriptive statistics.

The overall severity of TLC was reported as both the mean (±Standard Deviation) and the median number of days lost and grouped according to the time lost — namely, slight (0 days), minimal (1-3 days), mild (4-7 days), moderate (8-28 days), severe (29 days-6 months) and long-term (>6 months) (Pluim et al., 2009).

RESULTS

The anthropometric characteristics of the players are reported in Table 1.

Table 1. Anthropometric characteristics of the first fifty players of the ATP ranking (20th February 2022).

	Age (yrs)	Body mass (kg)	Height (m)	BMI (kg/m2)
Mean ±SD	27.7±4.9	81.3±8.9	1.89±0.09	22.3±1.3
Range	18.3-37.3	64-108	1.70-2.11	19.8-24.8

BMI: Body Mass Index.

In the five years period 267 TLC were recorded (Table 2), 137 of them occurred or were reported during the tournaments (51%) and 130 during training sessions (49%). Recurrences were 31% affecting twenty-seven players (54%).

Table 2. Locations of all the recorded medical conditions.

LOCATIONS		N°	%
Head/Neck	Neck	3	1.1%
	Eye	1	0.4%
Upper limbs	Shoulder	26	9.7%
	Wrist	15	5.6%
	Elbow	10	3.7%
	Hand	3	1.1%
	Arm	2	0.7%
Trunk	Back	23	8.6%
	Abdomen	17	6.4%
	Chest	1	0.4%
Lower limbs	Shank	23	8.6%
	Foot	23	8.6%
	Knee	21	7.9%
	Thigh	19	7.1%
	Ankle	18	6.7%
	Hip	12	4.5%
Other	Hillness	38	14.2%
	Gastrointestinal	7	2.6%
	Pulmonary	3	1.1%
	Nervous system	1	0.4%
	Dental	1	0.4%
	Total	267	100.0%

Most of these TLC were treated conservatively (N=256; 96%; Table 3), while only 11 (4%) needed surgery (Table 4).

Table 3. Locations and diagnosis of medical conditions requiring surgery and their severity.

Location	Diagnosis	Days out from competitions	Severity
Shoulder	Rotator cuff injury	367	Long term
Ankle	Sprain	187	Long term
Hip	Arthrosis	153	Severe
Groin	Hernia	111	Severe
Foot	Heel spur	85	Severe
Elbow	Tendinopathy	61	Severe
Elbow	Tendinopathy	60	Severe
Abdomen	Hernia	43	Severe
Knee	Meniscopathy	26	Moderate
Ankle	Calcification	14	Moderate
Dental	Removal of wisdom tooth	10	Moderate

Considering all the TLC (n=267), the median time loss was 17 days (range 1-378; mean 33.2±48.1). For conditions requiring surgery (n=11), the median was 61 days (range 10-367; mean 102±105).

Table 4. Locations and severity of medical conditions treated conservatively. SD: Standard Deviation.

Location	N°	%	Days out from competitions				Severity
			Median	Min	Max	Mean ±SD	
Illness	48	18.8	10	1	183	24±29	Minimal to long term
Shoulder	25	9.8	16	3	100	27±25	Minimal to Severe
Back	23	9.0	8	2	179	22±41	Minimal to severe
Shank	22	8.6	16	3	179	30±38	Minimal to severe
Foot	22	8.6	12	1	128	31±39	Minimal to severe
Knee	20	7.8	22	5	99	31±26	Mild to severe
Thigh	18	7.0	18	4	190	33±44	Mild to severe
Abdomen	16	6.3	29	5	187	40±43	Mild to severe
Ankle	16	6.3	14	3	63	20±17	Minimal to severe
Wrist	15	5.9	27	7	378	61±101	Mild to long term
Hip	11	4.3	27	6	178	45±52	Mild to severe
Elbow	7	2.7	12	4	75	20±25	Mild to severe
Other	5	2.0	35	8	87	39±30	Mild to severe
Neck	3	1.2	25	1	110	45±57	Minimal to severe
Hand	3	1.2	10	6	13	10±5	Mild to moderate
Arm	2	0.8	69	10	127	69±83	Moderate to severe
ALL	**256**	**100.0**	**17**	**1**	**378**	**30±42**	**Minimal to long term**

Table 5. Time-loss by diagnosis and severity. SD: Standard deviation.

Diagnosis	N°	%	Days out from competitions				Severity
			Median	Min	Max	Mean ±SD	
Muscle tear	50	19.5	18	1	190	34±44	Minimal to long term
Tendinopathy (shoulder)	23	9.0	17	3	378	45±89	Mild to long term
Back pain	22	8.6	8	2	179	19±37	Minimal to severe
COVID-19	22	8.6	17	6	63	26±19	Mild to severe
Blisters	18	7.0	12	1	94	17±22	Minimal to severe
Tendinopathy (unspecified)	17	6.6	34	6	127	41±32	Mild to severe
Sprain	16	6.3	21	3	63	26±20	Minimal to severe
Tendinopathy (wrist-hand)	15	5.9	12	3	128	29±44	Minimal to severe
Illness	13	5.1	6	4	38	10±10	Mild to severe
Knee problem	12	4.7	15	5	99	27±31	Mild to severe
Other	10	3.9	23	3	128	37±40	Minimal to severe
Tendinopathy (elbow)	7	2.7	12	4	75	20±25	Mild to severe
Gastrointestinal	6	2.3	10	8	28	15±9	Moderate
Hip problems	5	2.0	18	6	62	26±25	Mild to severe
Bone fracture	5	2.0	92	43	109	84±28	Severe
Arthrosis hip	4	1.6	32	10	178	63±77	Moderate to severe
Flu	4	1.6	6	4	9	6±3	Mild to moderate
Groin pain	4	1.6	23	17	36	25±8	Moderate to severe
Asthma	3	1.2	5	1	7	4±3	Minimal to mild
ALL	**256**	**100.0**	**17**	**1**	**378**	**30±42**	**Minimal to long term**

Furthermore: 89% of blisters affected the feet, 88% of sprain affected the ankle, 34% of muscles injuries affected the shank, 32% of muscle injuries affected the abdominal muscles, 28% of muscle injuries affected the thigh. Among "Other" (Table 5) we listed cases of pain to the tibia, problem to clavicle, bone oedema to the elbow, eye problem, heat stroke, Müller-Weiss syndrome, and muscle cramps.

Finally, in the population considered we did not find significant relationships between number of TLC and age (R2=0.147) or ranking (R2=0.016) of the players.

DISCUSSION

The studies on medical conditions usually explore several aspects of the epidemiology of injuries, such as prevalence, incidence, injury rate, and mechanism of injury. These studies are almost always conducted without collecting information on times of return to competitions, although time-loss is an outcome that top tennis players want to minimize (Kovalchik, 2020).

To our knowledge, the present study is the first that try to highlight the effects of medical conditions on the continuity of the career of a selected group of top male tennis players. In the examined five-year period, we found that players suffered on average 5.3 TLC each ranging from 1 to 15, with a median time-loss of 17 days (i.e., moderate severity), reaching 61 days (i.e., severe) when surgery was needed. Moreover, there was a wide variance of the time-loss, from minimal severity to long term, resulting from the different medical conditions depending on type, nature, and possibility of therapy or management. In fact, in some cases, and in particular of chronic conditions, affected players can participate in the tournaments or shorten the length of time-loss utilizing different form of therapies, including non-steroidal anti-inflammatory drugs (NSAIDs), topical analgesics, injectable NSAIDs, local anesthetics (Bourgonjon et al. 2022), prolotherapy (Zhu et al., 2022), extracorporeal shock wave therapy (Ozturan et al., 2010), and even injections of corticosteroids or platelet rich plasma (Kemp et al., 2021).

In our study we did not find significant relationships between the number of TLC and the age of the players, probably because of the small number of subjects and the limited time span explored. Indeed, a recent analysis of tens of thousands of competition weeks over the complete professional careers of 389 top male tennis players found significant increases in the risk of time-loss from competition with greater total competition load (Kovalchik, 2020). It was also demonstrated that the risk for the same increase in load increased with a player's biological age, indicating that the harmful effects of load are magnified for older players compared to younger players (Kovalchik, 2020).

As for the diagnosis, 45% of the injuries recorded in the present study were due to tendinopathies (26%; 9% were recurrences) and muscle tears (20%; 12% were recurrences), meaning that the musculo-tendinous unit is particularly sensitive to the effects of training and competition loads of tennis. Indeed, Colberg et al. (2015) in their study reported that one out of four athletes had a gradual onset condition that was commonly attributed to the training environment and length of each training session.

Our data confirm that lower limbs were the locations most affected by injuries (43% of all TLC) (Fu et al., 2018, Pluim et al., 2016), followed by upper limbs (21%) and trunk (15%), while illnesses were 19%. In our study, injuries, as opposed to illnesses, accounted for 81% of all TLC, similar to previous findings of 80% (Hartwell et al., 2017) and 78% (Okholm Kryger et al., 2015), indicating a consistent trend in different samples of tennis players. It is interesting to note that the Covid-19 pandemic affected twenty-two players i.e., 44% of our sample, with a time-loss severity between one week and two months, leading to consider the importance of adopting preventive measures in the sporting context to manage the danger of transmissible illnesses.

LIMITATIONS

This is an observational retrospective study, in which the use of different web and media sources of information posed a challenge to data collection and understanding of the circumstances of the injuries. These sources allow for the collection of limited data regarding injuries and illnesses and their accurate diagnosis, so it is challenging to obtain detailed information about the casualty and precisely analyze it. As an example, sometimes websites reported an unspecified "problem" such as "muscular problem" or "problem to the ankle" which prevent from a correct classification, especially for medical condition occurred out of competitions which is difficult to confirm by multiple web reports. Furthermore, an absence of data identified in the search does not necessarily equate to an absence of cases leading to a possible underestimation of the results. For example, minor injuries sustained during match play do not prevent from finishing the match (Colberg et al., 2015) and cannot appear in our study. Another limit is the small number of players and the time span restricted to 5 years.

Despite these limitations, this study still provides an idea on the main conditions that lead to absence from training and/or tennis tournaments and their severity, which should be investigated with further prospective studies.

CONCLUSIONS

This short paper focuses on the medical conditions entailing time-loss in top ranked ATP tennis players. Our results agree with most of the published data regarding tennis epidemiology, adding for the first time, some information about the severity of these conditions. Considering that time-loss is an outcome that top tennis players want to minimize, it became clear that both players and coaches should implement all the measures aimed to prevent the consequences of any kind of condition, especially those due to functional overload and transmissible illnesses. Nonetheless, Güler and Abdio?lu (2022) observed that many male tennis players they studied did not take precautions for sports injuries.

Prevention should start early in the career of tennis players, from childhood where early specialization and high training volumes may increase risk for injury (Rose et al., 2008), although early intense training seems to be non-essential for attaining an elite level in all sports (Jayanthi et al., 2013), tennis included. Literature data show that players who specialized only in tennis were 1.5 times more likely to report an injury (Jayanthi et al., 2011), and medical withdrawals increased in national tennis players after playing more than five matches per year in supernational tournaments (Jayanthi et al., 2009).

It is well known that training has protective effects against injuries (Gabbett, 2016), but principle of load progression means that from beginners to elite athletes the training workload must increase gradually, and be varied periodically according to athlete's physiological capacity, psychological abilities, and work tolerance (Bompa & Haff, 2009), deeply understanding the training process leading to elite performance (Smith, 2003), without forgetting tennis-specific exercises such as decelerations (Kovacs et al., 2008).

As far as elite athletes are concerned, prevention should consider not only training loads, but also playing surfaces (Alexander et al., 2022) and overall lifestyle including nutrition and sleep, together with other healthy measures such as vaccinations (Edouard et al., 2019), especially for players traveling around the world.

Players and coaching staff should know the effects of medical conditions on the career of a tennis player and how to set up an effective prevention program aimed at minimizing the risk of medical conditions. We think that this paper can help.

Further prospective studies are necessary to better understand the relationships between risk factors and severity of medical conditions, looking for injury prevention and health promotion of all the tennis players.

CONFLICT OF INTERESTS AND FUNDING

The authors declare that they do not have any conflict of interest and that they did not receive any funding to conduct the research.

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Influential literature in tennis medicine and science

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ABSTRACT

This study examined the most influential peer-reviewed journal articles and books in tennis medicine and science based on citations (C). Systematic searches were performed to extract authors, titles, year, journal, C, and research focus for the top cited publications indexed in Google Scholar (GS). The top 100 articles had high numbers of citations (85 to 1,164) and citation rates (3 to 41 C/year) that were similar between tennis medicine and science, with fewer citations to tennis books. The influence of tennis research has increased over the last decade, with citations and citation rates were higher than was previously reported (Knudson, 2012). The study confirmed important research topics and journal outlets and identified influential authors. Influential tennis research continues to focus on injuries, physiological and psychological factors, with recent increases in analytics and business aspects of the sport.

Key words: bibliometrics, book, citation, impact.

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INTRODUCTION

There is worldwide interest in tennis as a recreational, competitive, and spectator sport. The health benefits and injuries of a lifetime sport like tennis result in considerable scientific interest. Several scientific and professional journals publish research on tennis, particularly tennis medicine and sport science. There are even several journals that specialize in tennis medicine and science like the International Journal of Racket Sport Science, the ITF Coaching & Sport Science Review, and the Journal of Medicine & Science in Tennis.

There has been initial bibliometric research on these specialized journals (Crespo & Over, 2010; Knudson, 2020; Knudson & Myers, 2021) and in Chinese publications (Yuhan, 2016). The development of knowledge in tennis medicine and science throughout the wider scientific literature, however, is less well known. One study documented the most cited original research, reviews, and books in tennis using Google Scholar (Knudson, 2012). This study found that the top 30 cited research articles emphasized sports medicine, exercise physiology, biomechanics, and psychology topics. Interestingly, original research articles were cited more frequently than review articles, with even fewer citations to tennis books. Bibliometric research often focusses on metrics derived from citations (C) to determine the usage, influence, or impact of published research (Knudson, 2019). A decade has passed since the Knudson (2012) study and research and journal outlets have dramatically expanded, so there was a need to update the most influential research in tennis medicine and science. The aim of this study was to document the most cited peer-reviewed journal articles and books in tennis medicine and science. The study identified the 100 most cited journal articles in both tennis medicine and tennis science, as well as the twenty most cited tennis books. This may confirm trends reported in previous work and expand knowledge of influential research topics, journals, and authors in tennis.

METHOD

The study used the Google Scholar (GS) bibliometric service given its superior coverage of peer-reviewed literature compared to curated databases (e.g., CINAHL, PubMed, Scopus, SPORTDiscus, Web of Science) and other open (e.g., Dimensions) bibliometric services (Delgado-Lopez-Cozar & Cabezas-Clavjo, 2013; Halevi et al., 2017: Harzing & Alakangas, 2016; Martin-Martin et al., 2018, 2021; Meho & Yang, 2007; Walters, 2009). The advantage of more complete coverage of peer-reviewed publications comes at the cost of greater manual searching, extracting, and checking of

bibliometric records (Halevi et al., 2017; Schultz, 2007). This greater demand on the investigator in data extraction, review, and analysis was accepted to overcome the limited coverage and search engine errors common in most databases (Gusenbauer & Haddaway, 2020).

The GS database service was used to perform multiple searches using "tennis" and combinations of "tennis" with "science" and "medicine." The large numbers of GS indexed records ("tennis" returned "about 1.3 million records", "tennis and medicine" 486,000, and "tennis and science" 712,000), however, were not a problem for identifying the most cited publications. The GS algorithm returns only the top 1000 records, but they correspond roughly to descending order by citations. This combined with the strong positive skew of citations to scientific publications (Knudson, 2015; Opthof et al., 2004; Seglen, 1992) ensures that identification of the top 100 cited articles and top 20 cited books could be reliability achieved with careful, manual review. A positive skew means citations are not symmetrically distributed, with most citations in fewer highly cited publications, and fewer citations in a long "tail" of numerous publications with few or even no citations. The investigator manually accessed and reviewed all 3000 records for the three searches. For many searches, later records could be more easily scanned because they receive very few citations and sometimes include grey literature (Haddaway et al., 2015) that were not the focus of this study. Grey literature refers to non-profit publications by academics, businesses/organizations, or governments like technical reports, theses, conference abstracts, and white papers.

Two kinds of indexed publications on tennis were the focus of this study: research reports published in peer-reviewed journals and books. This study included both original research and review articles in the research reports extracted. Studies were considered focused on tennis if the topic was primarily on the sport, related medical conditions (e.g., epicondylosis; tennis leg), or tennis players. Chapters, proceeding articles, and patents were excluded. Studies comparing tennis players with controls or one other sport were included, while studies and reviews focusing on more than two sports including tennis were excluded. Studies comparing numerous sports are more likely to attract citations related to other sports and not specifically tennis.

GS and publication data for over 330 articles and 21 books were entered into an Excel spreadsheet to ensure that the top cited publications were obtained. Searches occurred during the first week in August 2023 and ended before GS refresh on August 8, 2023. The investigator used a combination of GS data and accessed the hyperlink to the original source to confirm the authors, title, source, year of publication, and citations (C). Author surname and initials were extracted for up to the first four authors, with an annotation made if there were more coauthors. GS citation rate was also calculated (CR = C/(2023-year published). Data were reviewed for errors and incorrect inclusion before proceeding to analysis.

The investigator subjectively classified the topic of each highly cited journal article and book into one of seven categories: Analytics/Coaching, Biomechanics, Exercise Physiology/Fitness, Multdisiciplinary, Psychology/Sociology/Motor Behavior, Sports Business, and Sports Medicine. Articles with two topics were classified based on the primary study question and articles with more than two topics were classified as Multidiscplinary. The top 100 cited articles classified as Sports Medicine were identified and compared to the top 100 cited with all other classifications. This combination of articles from other categories was considered the tennis sports science group. The focus on two areas of tennis research (medicine and science) was selected given the dominance (56-63%) of sports medicine in a previous study of tennis citation classics (Knudson, 2012). The larger and more diverse sample in this study promises to provide a superior description of influential tennis research.

Descriptive data were calculated using JMP Pro 14 (SAS Institute, Cary, NC). Content analysis was performed on article topic data. Citations and content of the most cited tennis publications were compared to previous studies of influential tennis medicine and science research (Knudson, 2012, 2021; Knudson & Myers, 2021).

RESULTS

The top 100 journal articles in tennis medicine and tennis science had 24,241 and 23,750 GS indexed citations, respectively. Descriptive data of article influence were also similar between primarily tennis medicine and tennis science (Table 1). Top cited tennis medicine articles were more skewed (γ = 2.3) than tennis science (γ = 1.7). Ninety of the top tennis medicine articles were citation classics, while all top 100 tennis science articles were citation classics. Citation classics are highly cited publications in a specific research area or specialization, usually defined as 100 or more (Gehanno, 2007, Knudson, 2012). Almost half of the citations in both areas were dominated by four journals. Highly cited tennis sports medicine articles were published most often in British Journal of Sports Medicine (21%), American Journal of Sports Medicine (11%), Journal of Bone and Joint Surgery (7%), and Clinics in Sports Medicine (7%). Highly cited tennis sports science articles appeared more often in the British Journal of Sports Medicine (16%), Medicine and Science in Sports and Exercise (11%), American Journal of Sports Medicine (9%), and Journal of Sports Sciences (9%).

Most top cited tennis medicine articles focused on tennis elbow (39%), injury epidemiology (13%), shoulder injury (7%), bone development (5%), and heat illness (4%). The top 100 cited tennis science articles included all topical categories with relatively more papers in Exercise Physiology/Fitness (46%) and Biomechanics and Psychology/Sociology/Motor Behavior both with 22%. Table 2 lists the 20 most cited articles in tennis medicine and science, as well as the top 17 cited tennis books.

Table 1

Influence statistics for the top cited 100 journal articles indexed in Google Scholar.

	Mean	SD	Max	75th	Me	25th	Min
Tennis Medicine							
Citations	242	206	1,164	284	155	123	85
CR	11.6	8.5	41.3	14.3	9.1	5.5	2.2
Tennis Science							
Citations	238	136	765	279	186	140	116
CR	12.7	7.2	35.3	16.4	10.8	8.0	2.8

Note: Citation Rate (CR) = Citations/(2023-year published) and median (Me).

Table 2

Highest cited tennis journal articles and books.

Tennis Medicine				
Author	**Year**	**Title**	**Journal**	**C**
Nirschl RP et al.	1979	Surgical treatment of lateral . . .	J Bone Joint Surg	1,164
Kannus P et al.	1995	Effect of starting age of physical . . .	Ann Inter Med	990
Kraushaar BS et al.	1999	Tendinosis of the elbow . . .	J Bone Joint Surg	932
Roles NC et al.	1972	Radial tunnel syndrome . . .	Bone Joint J	733
Bisset L et al.	2006	Mobilisation with movement . . .	Br Med J	702
Nirschl RP	1992	Elbow tendinosis/tennis elbow	Clinics Sports Med	683
Haapasalo H et al.	2000	Exercise-induced bone gain . . .	Bone	657
Bass SL et al.	2002	The effect of mechanical loading . . .	J Bone Min Res	632
Bisset L et al.	2005	A systematic review and meta . . .	Br J Sports Med	631
Coonrad RW et al.	1973	Tennis elbow: Its course . . .	J Bone Joint Surg	608
Sharma R et al.	2002	Physiologic limits of left . . .	J Am Col Cardio	473
Vergaar JAN	1994	Tennis elbow	Int Orthopaedics	428
Pluim BM et al.	2006	Tennis injuries: Occurrence . . .	Br J Sports Med	424
Huddleston AL et al.	1980	Bone mass in lifetime tennis . . .	J Am Med Assoc	419
Kibler WB	1995	Biomechanical analysis of the . . .	Clinics Sports Med	389
Bjordal JM et al.	2008	A systematic review with . . .	BMC Musculosk DIsord	379
Gruchow et al.	1979	An epidemiological study of tennis . . .	Am J Sports Med	353
Boyer MI et al.	1999	Lateral tennis elbow: Is there . . .	J Shoulder Elbow Surg	350
Nirschl RP et al.	2003	Elbow tendinopathy . . .	Clinics Sports Med	347
Kibler WB et al.	1996	Shoulder range of motion in elite . . .	Am J Sports Med	323
Tennis Science				
Gould D et al.	1996	Burnout in competitive junior tennis. . .	Sport Psych	765
Williams AM et al.	2002	Anticipation skills in a real. . .	J Exp Psych	676
Fernandez-Fernandez J et al.	2006	Intensity of tennis match play	Br J Sports Med	600
McPherson SL et al.	1989	Relation of knowledge and . . .	Res Quart Exerc Sport	557
Kovacs MS	2007	Tennis physiology: training . . .	Sports Med	542
O'Donoghue P et al	2001	A notational analysis of elite . . .	J Sports Sciences	542
Lees A	2003	Science and the major racket . . .	J Sports Sciences	516
Gould D et al.	1996	Burnout in competitive junior . . .	Sport Psych	506
Kovacs MS	2006	Applied physiology of tennis . . .	Br J Sports Med	502
Ward P et al.	2002	Visual search and biological . . .	Res Quart Exerc Sport	442
Ellenbecker TS et al.	2002	Glenohumeral joint rotation . . .	Med Sci Sports Exerc	432
Elliott B	2006	Biomechanics of tennis	Br J Sports Med	424
Smekal G et al.	2001	A physiological profile of tennis . . .	Med Sci Sports Exerc	422

Kraemer WJ et al.	2000	Influence of resistance training . . .	Am J Sports Med	401
Elliott B et al.	2003	Technique effects on upper . . .	J Sci Med Sport	372
Elliott B et al.	1995	Contributions of upper limb . . .	J Appl Biomech	350
Fernandez-Fernandez J et al.	2009	A review of the activity profile . . .	Strength Cond J	330
Kraemer WJ et al.	2003	Physiological changes with . . .	Med Sci Sports Exerc	330
Chandler TJ et al.	1990	Flexibility comparisons of junior . . .	Am J Sports Med	330
Bergeron MF et al.	1991	Tennis: A physiological profile . . .	Int J Sports Med	311

Tennis Books

Author	Year	Title	Publisher	C
Gallwey WT	1975	The inner game of tennis (Mult. Editions)	Macmillan	1,877
Brody H	1987	Tennis science for tennis players	Univ Penn Press	198
Kovacs MS et al.	2016	Complete conditioning . . . (2 editions)	Human Kinetics	177
Groppel JL	1992	High-tech tennis (2 editions)	Leisure Press	164
Brody H et al.	2002	The physics and technology of tennis	Rac Tech Pub	152
Elliott BC et al.	2003	Biomechanics of advanced tennis	Int Tennis Fed	105
Baltzell ED	2017	Sporting gentlemen: Men' tennis . . .	Taylor Francis	95
Roetert EP et al.	2001	World-class tennis technique	Human Kinetics	93
Loehr J	1990	The mental game: winning . . .	S Greene Press	86
Knudson D	2006	Biomechanical principles of tennis . . .	Rac Tech Pub	71
Chu DA	1995	Power tennis training	Human Kinetics	68
Braden V et al.	1998	Tennis 2000: Strokes . . . (2 editions)	Little Brown	65
Plagenhoef S	1970	Fundamentals of tennis	Prentice Hall	54
Roetert EP et al.	2019	Tennis anatomy	Human Kinetics	52
Kovacs M et al.	2007	Tennis training: enhancing . . .	Rac Tech Pub	49
Pluim BM et al.	2004	From breakpoint to advantage . . .	Rac Tech Pub	49
Elliott B et al.	1983	The art and science of tennis	Sanders	49

The most prolific authors of highly cited research were different between tennis medicine and tennis science (Table 3). The top cited authors in tennis medicine focused on tennis elbow, injuries, bone development, and heat illness. The top cited dozen authors in tennis science focused on all topic categories and primarily biomechanics, fitness, physiology, and psychology.

Table 3
Top authors and number of coauthored articles in top 100 cited tennis medicine and science publications.

Tennis Medicine	n	Tennis Science	n
Nirschl RP	8	Fernandez-Fernandez J	11
Haapasalo H	5	Ellenbecker TS	8
Kannus P	5	Elliott BC	7
Kibler WB	5	Gould D	7
Bergeron MF	4	McPherson SL	7
Pluim BM	4	Roetert RP	7
Sievanen H	4	Reid M	6
Bisset L	3	Girard O	4
Renstrom PA	3	Mendez-Villanueva A	4
Kontulainen S	3	Sanz-Rivas D	4
Sobel J	3	Kovacs MS	3
Ellenbecker TS	2	Kraemer WJ	3

DISCUSSION

This study confirmed that research interest in tennis medicine and science has continued to grow over the last decade. The top 25% cited articles in this study (Table 1) had between 279 and 1,163 citations which was higher than the 113 to 499 citations for tennis articles in July of 2012 (Knudson, 2012). The high citation totals and citation rates in the current study (Table 1) were similar between tennis medicine and tennis science research. This indicates that there is approximately equal influence and knowledge development in both medical and sport science areas. Inspection of Table 1 shows that influential tennis research with high citation totals result from both long-term relevance with lower citation rates (4 - 19 C/year) and more recent articles that represent hot topics with higher citation rates (> 20 C/year). A current GS search "tennis" returns "About 1.3 million" records compared to the 550,000 reported a decade ago (Knudson, 2012). The expansion of research and journal outlets may also contribute to the increasing citation of tennis medicine and science research.

Separating tennis medicine from tennis science topics shows more journals for the former (45) than the latter (27) publishing the top cited 100 articles indexed in GS. While a few sports medicine journals publish about half of the highly cited tennis research (British Journal of Sports Medicine, American Journal of Sports Medicine, Medicine and Science in Sports and Exercise), influential tennis medicine and science is published in a variety of multidisciplinary and specialized journals. One ITF Coaching & Sport Science Review article was in the top 100 most cited tennis science articles (Cross & Pollard, 2009), having 131 citations and a citation rate (9.4) higher than is common in highly specialized journals (Knudson, 2020; Knudson & Myers, 2021; Postma, 2007). Scholars interested in tennis research should search a variety of bibliometric databases to be sure to identify relevant research (Gusenbauer & Haddaway, 2020; Knudson, 2019).

The most highly cited tennis journal articles focused on tennis injuries/tennis elbow, physiology/fitness, biomechanics, and psychological/motor behavior topics. This was in general agreement with the five disciplinary areas reported in the Knudson (2012) study of tennis citation classics. New observations of the current study (larger with more topic areas) were the appearance of top cited tennis research in analytics/coaching (8%) and business/management (3%) aspects of the sport. The top cited books in the current study did confirm several observations of the previous study of tennis citation classics (Knudson, 2012): lower citations (60-70%) to books than journal articles, a majority on biomechanics (41 – 60%), and the fewest on sports medicine (5-7%).

Another novel observation of the current larger study of tennis research is the identification of influential researchers. Many of the authors of citation classics in tennis original research, reviews, and books reported in the previous study by Knudson (2012) were confirmed in the present study. Inspection of table 3 confirms highly influential authors of tennis sports medicine research on tennis elbow (RP Nirschl, L Bisset), heat illness (MF Bergeron), bone (H Haapasalo, P Kannus), and injuries and their treatment (WB Kibler, BM Pluim; PA Renstrom). The current study was able to identify that influential researchers in tennis science were different from tennis medicine and new influential researchers in topics with accelerating rates of citation. The most frequent authors in tennis science tended to publish in the Exercise Physiology/Fitness topic, both over a long time (TS Ellenbecker, EP Roetert) and in the last 15 years (J Fernandez-Fernandez). Influential long-term authors in tennis biomechanics (BC Elliott), psychology (D Gould), and motor learning (SL McPherson) were identified. A higher percentage of greater than four authors per article was observed in tennis medicine articles (37%) than in tennis science (22%). Future tennis bibliometric research should strive to replicate and extend these results on current authorship and research topics. Greater detail on knowledge development in tennis using interdisciplinary teams of scholars and on sport-specific topics would assist both coaches, researchers, and tennis organizations.

The results of this study should be interpreted in the context of its limitations. There is potential for error in the manual searching, extraction, entry, and cleaning of GS data. The lack of curation of GS and the unknown accuracy and reliability of the classification of primary topics by the investigator are also limitations. Focus on the top cited work is standard in bibliometrics, however limits the identification of potentially influential recent publications that do not have enough time to accrue citations, particularly in small fields like tennis medicine and science. The extensive coverage of GS, the high correlations between citations from GS and other curated databases (Knudson, 2019, 2022), the consistency of the study results with previous studies, and large sample however, all indicate the limitations do not likely bias the results of this study.

CONCLUSION

It was concluded that the influence of tennis research has increased based on increases in current citations in GS compared to a previous study (Knudson, 2012). The high citations and citation rates are approximately equal between top cited tennis medicine and tennis science journal articles, with fewer citations seen to top cited tennis books. Influential tennis research continues to focus on injuries, physiological and psychological factors, with recent increases in the analytics and business aspects of the sport.

CONFLICT OF INTEREST AND FUDING

The author has no conflict of interest to declare and did not receive funding to conduct this research.

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Factors that enable breakthroughs in tennis: A case study of elite college tennis players in Japan

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ABSTRACT

In the world of sports, the phenomenon of a dramatic improvement in competition results at some point is called a "breakthrough." In this study, "breakthrough" is defined as "a dramatic improvement in competition results at some point," and the purpose of this study is to reveal hypothetical findings on the factors that enable "breakthroughs" in tennis. Semi-structured interviews were conducted with eight Japanese college tennis players who had experienced a "breakthrough" in the past, and who had records of being in the top 8 or above in national championships. The interview content was transcribed and used to conduct a qualitative analysis. As a result, the following three hypothetical findings were revealed: "maintaining high motivation," "continuous growth," and "high performance during games" are important for enabling "breakthroughs" in tennis. Those hypothetical findings will be useful information for athletes who are aiming for "breakthroughs" and for coaches who support them.

Key words: breakthrough, expertise, tennis, qualitative research.

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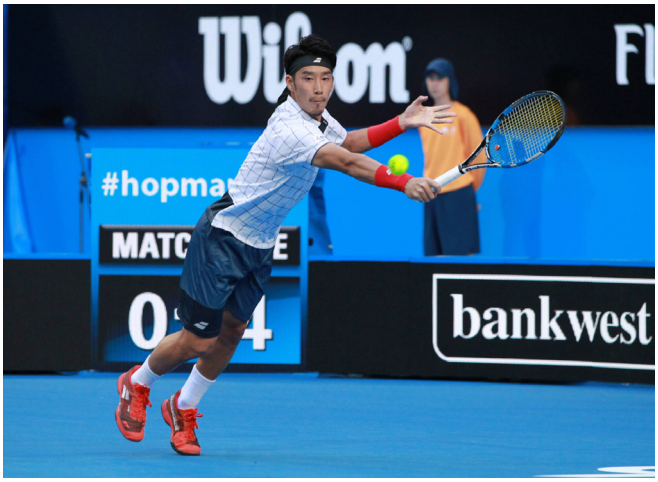
INTRODUCTION

In the world of sports, the phenomenon of a dramatic improvement in competition results at some point is called a "breakthrough." The word "breakthrough" generally refers to breaking through a difficulty or barrier. In the world of sports, at the Laureus World Sports Awards, also known as the Academy Awards of the sports world, Laureus World Breakthrough of the Year is awarded to athletes who show rapid growth throughout the year. Thus, the word "breakthrough" has become a keyword that attracts attention in the sports world.

Roger Federer, the former number one tennis player, and a six-time Laureus World Sportsman of the Year laureate, said in an interview, "2003 was a breakthrough year for me" (Tennis Classic editorial department, 2020). Ranked 3rd in the world at the time, he won his first title at the Nitto ATP Finals and moved up to No. 2 in the world rankings. In that tournament, he defeated Andre Agassi, the former No.1 player, and looked back, saying, "It opened up my belief that I could fight and defeat the best baseliner head-on" (Tennis Classic editorial department, 2020). Then, two months later, he won the Australian Open and took over the world rankings and held that position until August 2008.

In addition, Naomi Osaka, a former world champion, became the first Japanese player to win the Laureus World Breakthrough of the Year in February 2019. She jumped from No.68 in the world rankings at the end of 2017 to No.1 after winning the US Open in August 2018 and the Australian Open in January 2019.



The phenomenon of a dramatic improvement in competition results at some point in sports is conceivable this way. And the interest of this research is to find out what factors enable "breakthroughs." There are no studies, yet, dealing with "breakthroughs" in the field of sports and there is no clear definition of what a "breakthrough" is. Therefore, in this study, "breakthrough" is operationally defined as "a dramatic improvement in competition results at some point."

In reviewing the previous studies relating to "breakthroughs," we can study those that have acquired advanced knowledge and skills in a specific field (otherwise known as experts). Research has also been conducted to reveal how these experts acquired their skills. For example, Ericsson (1996)

proposes that it takes more than ten years of practice and experience to acquire high levels of knowledge and skills. Furthermore, it has been stated that it is not enough just to go through ten years of practice and experience and that the practice must be a "deliberate practice" that requires a high level of concentration and effort (Ericsson et al.,1993).

Therefore, it is conceivable that the development of skills may be an important factor that enables a "breakthrough." But, if a "breakthrough" is defined as "a dramatic improvement in competition results," it is necessary to understand "breakthroughs" from a more comprehensive perspective, including the perspective of acquisition of advanced knowledge and skills, the perspective of changes in competition results, and the clarification of factors behind such "breakthroughs."

Due to the paucity of previous research on "breakthroughs," it is difficult to hypothesize factors that enable such a scenario. Therefore, it is necessary to conduct exploratory research aimed at generating hypothetical findings on factors that enable "breakthroughs." Qualitative research is said to be an effective research method for exploratory research into unknown phenomena and the characteristics of people's experiences (Nochi, 2000).

Therefore, in this study, we conduct qualitative research focusing on the experiences of tennis players who have experienced "breakthroughs" in the past and reveal hypothetical findings on factors that enable such instances. The hypothetical findings of this study are thought to be of useful information for athletes aiming for "breakthroughs" and for coaches who support them.

METHODS AND PROCEDURES

Subject

The subjects of this study were Japanese college tennis players who had experienced "breakthroughs" in the past and had won top prizes in the national championships in Japan. The subjects of this study are shown in Table 1. It is hoped that the subjects of this study remember episodes of their "breakthroughs" and the factors that made it possible. Therefore, in this study, the following two selection criteria were used to select the survey subjects. (1) Have experienced "breakthroughs" in a tennis competition in the past, and (2) achieved top 8 or higher in an individual game at a national championship. The reason for this is that it is expected that national top-class college athletes have more episodes of "breakthroughs" than other athletes.

The subjects of this study were eight Japanese college tennis players (four males and four females, average age 19.9±0.6 years) who met the above two selection criteria and cooperated in the survey. The study was conducted after confirming that the above two selection criteria were met.

Table 1

Attribute of subjects .

Subjects	Gender	Age	Best Results in National Championship
A	Male	21	Winner
B	Male	20	Winner
C	Female	20	Winner
D	Female	20	Winner
E	Female	20	Runner-up
F	Female	19	Runner-up
G	Male	20	Quarterfinals
H	Male	19	Quarterfinals

Procedure

The survey period was from April 2021 to November 2022. In this study, a semi-structured interview method was adopted. The survey was conducted online (videoconferencing using Zoom) and lasted 40 to 100 minutes (an average of about 68 minutes). The interview was centered on the question "Looking back on your career, when do you think you had your breakthrough?" "Why do you think 'breakthroughs' are possible?" and the interviewees were asked to give specific episodes in their answers.

In addition, as ethical considerations, the survey participants were informed of the right to refuse participation in the study, of the handling of their personal information, and that their anonymity would be preserved. They were also informed of the necessity to record the contents of the interviews to transcribe them into text. They survey was conducted after obtaining their consent.

Data Analysis

A qualitative inductive analysis was conducted. The procedure is as follows. First, we made a verbatim transcript of the self-talk data. Next, sentences that were related to factors that enable "breakthroughs" were extracted from the verbatim transcript of 90855 characters. The 101 extracted sentences were separated by meaningful phrases and codes. Codes were grouped according to the similarity of their contents and subcategorized with appropriate and concise words. Subcategories were grouped according to the similarity of their contents and categorized with appropriate and concise words.

RESULTS

As a result of the analysis of the interview content, the 101 semantic units were classified into 13 subcategories, and finally into three categories: "maintaining high motivation," "continuous growth," and "high performance during games" (Table 2).

The contents of each category and subcategory are described in detail below. The codes representing the categories and subcategories and the utterance data are shown in Tables 3, 4, and 5. The codes are denoted by【 】, subcategories by < >, and categories by « ».

Table 2
Overall Results

Category	Subcategory	Subjects							
		A	B	C	D	E	F	G	H
maintaining high motivation	setting achievable goals	○	○	○			○	○	
	setting goals related to the skill		○	○		○			○
	having a reason	○					○	○	○
	observing games			○	○		○		
continuous growth	increasing practice		○	○		○	○	○	○
	practicing with better players	○		○		○		○	○
	recognizing own strengths and weaknesses	○	○	○		○	○		○
	trying new ideas	○		○		○		○	○
	escaping from mistaken beliefs			○		○		○	○
high performance during games	match emulation	○				○	○	○	
	game repetition			○	○		○		
	focusing on what should be done	○				○		○	
	taking it easy		○	○	○	○			○

Place a "○" for subjects with a self-talk that corresponds to the subcategory.

Maintaining high motivation

In the category of «maintaining high motivation», the content is related to motivation for continuing daily practice and training (Table 3-1). This category consists of four subcategories: <setting achievable goals>, <setting goals related to the skill>, <having a reason>, and <observing games>.

First, in the subcategory of <setting achievable goals>, it was shown that the goal should be set as high and clear as possible within the feasibility of the goal. Next, in the subcategory of <setting goals related to the skill>, it was shown that setting a goal related to their play, in addition to achievement goals at competitions was important. Next, in the subcategory of <having a reason>, it was shown that the reason for aiming to achieve the goal should be clarified, such as "I want to win for the sake of..." Next, in the subcategory of <observing games>, the importance of visiting and watching target competitions and matches was shown.

Continuous growth

In the category of «continuous growth», the content is related to continuing to improve competitiveness (Table 3-2). This category consists of five subcategories: <increasing practice>, <practicing with better players>, <recognizing own strengths and weaknesses>, <trying new ideas>, and <escaping from mistaken beliefs>.

First, in the subcategory of <increasing practice>, it was shown that increasing the amount of practice due to changes in the environment, and time for independent practice due to going on to schools of higher education was important. Next, in the subcategory of <practicing with better players>, it was shown that creating opportunities to practice with players who are at a higher level or who are better at certain skills was important. Next, in the subcategory of <recognizing own strengths and weaknesses>, it was shown that understanding one's own strengths and weaknesses through feedback from coaches, self-analysis, and review of matches was important. Next, in the subcategory of <trying new ideas>, it was shown that to improve one's skills, continuing to make changes based on what one noticed in matches and feedback from coaches was important. Next, in the subcategory of <escaping from mistaken beliefs>, it was shown that breaking free from one's own false common sense, which had been formed by accumulating experience and knowledge, was important.

High performance during games

In the category of «high performance during games», the content is related to demonstrating the skills developed through practice and training in an environment different from practice, such as a match (Table 3-3). This category consists of four subcategories: <match emulation>, <game repetition>, <focusing on what should be done>, and <taking it easy>.

First, in the subcategory of <match emulation>, it was shown that daily practice should be approached with pressure like that of a game. Next, in the subcategory of <game repetition>, it was shown that to get accustomed to the environment of the game, which is different from daily practices, experiencing many opportunities of the game was important. Next, in the subcategory of <focusing on what should be done>, it was shown that regardless of the opponent's level, clarifying what one should do during the game and playing without hesitation was important. Next, in the subcategory of <taking it easy>, it was shown that approaching the games with less excessive expectations towards themselves and less excessive attachment to winning or losing was important.

Table 3-1

Typical utterance of «maintaining high motivation».

«maintaining high motivation»
＜setting achievable goals＞
【Set goals that can get serious】I think the breakthrough moment is the moment when you want to win a tournament or when you are serious about it. When you have a goal, and you are serious about it, you will notice a lot of things while you are playing. [Subject A] 【Set clear goal】First, set a clear goal in your mind. If you want to enter the main tournament, enter the main tournament, if you want to go to the national tournament, enter the national tournament. [Subject C]
＜setting goals related to the skill＞
【Set a goal of ideal play】I set goals for how I want to play. [Subject B] 【Practice to achieve ideal play】Rather than finding the issues, I practice thinking about how I want to play and how I want to be able to hit the ball. [Subject H]
＜having a reason＞
【The desire to win for higher education】I wanted to enter the high school of my choice. When I am under pressure to achieve results for that purpose, I may be motivated and become stronger. [Subject F] 【The desire not to lose for the sake of teammates】I feel that it was important for me to feel that I could not lose for the sake of my friends around me. This had a positive effect on me to the extent that I did not feel pressured. [Subject G]
＜observing games＞
【Go to the venue of the competition you are aiming for】You will not know what a national tournament is like or what the atmosphere is like unless you have been there. It is important to go there and think "I want to play here". [Subject D] 【Watching a tournament that was not able to compete in】I went to see the tournament that I lost in the qualifying round. When I saw people playing in that tournament, I felt even more that I wanted to play there myself. [Subject F]
Categories are denoted by « », subcategories by < >, codes by【 】, and subjects who spoke by [ ]

Table 3-2

Typical utterance of «continuous growth».

«continuous growth»
＜increasing practice＞
【Increased practice due to environmental changes】I think the amount of practice has increased a lot since I entered high school. I practiced from past 7:00 to around 8:00, went to club activities in the afternoon, and went to tennis school afterward. [Subject E] 【More time for self-practicing】If I did not have a good practice that day, I practiced by myself after that practice. I also practiced a lot by practicing in my free time or by asking my coach to practice with me. [Subject F]
＜practicing with better players＞
【Ask a higher-level player to practice with】I think it's important to practice with higher-level players. Practicing with higher-level players makes you realize more and makes you think that you have to reach this level to win. [Subject A] 【Practice with players who have the skills you want to learn】In my case, I am not good at doubles at all, so I have been practicing with a senior who is a strong doubles player. As a result, I am finally gaining confidence. [Subject H]
＜recognizing own strengths and weaknesses＞
【Finding strengths and weaknesses through self-analysis】It is important to do a thorough self-analysis and think about your strong points and your weak points. Specifically, you need to look at the games you played when you were good and determine what style of play you will adopt. [Subject B] 【Finding challenges from the game regardless of whether you win or lose】Sometimes I have perfect matches, but usually, I have problems whether I win or lose a match. Especially in losing matches, I know that this shot was not good enough, so I try to practice it. [Subject C]
＜trying new ideas＞
【Adopt and discard new skills】I believe that players who can adopt new skills and make a choice for them are the strongest. [Subject G] 【Make an exaggerated change】When we lost the national tournament last year, my persistence didn't work at all, and I realized that I had to attack. For about six months after that tournament, I made a conscious effort to play extremely aggressively in practice and competitions. [Subject A]
＜escaping from mistaken beliefs＞
【Escape from the assumption that offense is the only strategy】In practice, we often do offensive practice, such as chance ball practice and volleying practice. In addition, when I watch professional matches, points won by winners tend to be the focus, and that image has stuck in my mind. [Subject E] 【Understand the importance of reducing errors】Until now, I had an ideal pattern of attacking points, and I was obsessed with winning points with that pattern. However, after entering the university, I have come to understand that it is very important to be persistent and patient. [Subject E]
Categories are denoted by « », subcategories by < >, codes by【 】, and subjects who spoke by [ ]

Table 3-3.
Typical utterance of «high performance during games».

«high performance during games»
＜match emulation＞
【Increase tension in practice】The atmosphere in practice was so scary that I was not allowed to make mistakes. I think it was probably similar to the pressure in a game. Personally, the pressure to not make mistakes was greater than in games. [Subject G] 【Play a practice match under pressure】Unlike when I was in tennis school, I pushed myself in the matches within the club, as if I was the strongest player and should not lose to others. [Subject E]
＜game repetition＞
【Play the game until the game becomes like practice】I think it's important to play games regularly. Even if you practice a lot, it is completely different from playing matches. Winning or losing, it's important to get a feel for the game. [Subject D] 【Regularly compete in tournaments】I think it is important to participate in many tournaments. When I was a junior high school student, I used to participate in a tournament once a month, even though it was a low-grade tournament. I think it is important to have a good feel for the game. [Subject F]
＜focusing on what should be done＞
【Focus on what you can do, even if your opponent is strong】When I was playing against strong players, I did not want to be weak or to be pushed by pressure. I was conscious of playing my tennis no matter what my opponent was doing. [Subject A] 【Try not to get lost in the game.】If you want to play sticky, keep hitting the sticky ball and wait until you have a chance. On the other hand, if you want to play offensively, you need to keep hitting the ball offensively. Halfway is the worst. [Subject E]
＜taking it easy＞
【Play the game with a spirit of challenge】It's very nerve-wracking to play an important match against a superior player. So, I think it is a good idea to play every match as if you are going broke. [Subject D] 【Try not to be too conscious of winning or losing】I think I play well when I don't expect much from myself. It is not that I don't want to win, but when I don't care too much about winning or losing, the results are better. Maybe it is mental relaxation. [Subject B]
Categories are denoted by « », subcategories by < >, codes by【 】, and subjects who spoke by [ ]

DISCUSSION

The purpose of this study is to reveal hypothetical findings on the factor that enable "breakthroughs" in tennis. As a result, the following three hypothetical findings were revealed: "maintaining high motivation," "continuous growth," and "high performance during games" are important for enabling "breakthroughs" in tennis.

This suggests that to achieve a "breakthrough," in addition to improving competitive performance, it is necessary for one to carry out their daily practice and training with strong motivation and to be able to fully demonstrate their competitive ability in the special environment of competition, which is different from practice. From this point on, we will focus on each category and make a discussion.

Maintaining high motivation

To achieve a "breakthrough" in tennis, it is necessary to practice and train daily and continue to improve. Ericsson et al. (1993) showed that athletes who have reached the "professional" level have accumulated 10,000 hours of deliberate practice by the age of 20. Deliberate practice is defined as a practice that requires players to perform sophisticated tasks, provide feedback, repetition, error correction, and have a specific set of goals. It is also said a "painful" and "tedious" practice also requires dedication and commitment. To accumulate such practice without giving up, high motivation and mental strength are necessary. In fact, a study comparing the motivation of professional and amateur tennis players demonstrated that professional players have a higher level of motivation (Butt & Cox, 1992).

The subjects used various methods to stay highly motivated. First, in the subcategory of <setting achievable goals>, the importance of setting clear goals at appropriate heights was demonstrated. Goal setting theory (Locke & Latham, 1990) indicates the importance of goals being somewhat difficult and challenging, and of having concrete goals with numerical values and deadlines, rather than vague goals. In this manner, setting goals and the motivation to achieve them have been demonstrated to be essential factors in the growth of talented junior tennis players (Unierzyski, 2003).

Next, in the subcategory of <setting goals related to the skill>, the importance of having a goal for one's play was demonstrated. Dweck (1986) classifies achievement goals into two main categories: a performance goal and a learning goal. A performance goal is a goal that emphasizes relative advantage over others in comparison with others. A learning goal is a goal that emphasizes the development of one's abilities through learning and understanding. In the study of the relationship between goal orientation and intrinsic motivation in tennis competition, it was shown that task-oriented undergraduate tennis players exhibited high levels of intrinsic motivation (Duda et al., 1995).

Next, in the subcategory of <having a reason>, the importance of having a clear reason to win, such as "for my teammates" or "for higher education" was demonstrated. Such motivations are considered extrinsic motivations. Generally, extrinsic motivation is weaker than intrinsic motivation, such as "quitting the activity when the external reward is lost" or "giving up when suffering." However, self-determination theory (Ryan & Deci, 2002), which goes beyond the intrinsic/extrinsic framework and takes a more detailed view of motivation, distinguishes four types of extrinsic motivation based on the degree of autonomy: external adjustment, introjected adjustment, identified adjustment, and integrated adjustment. The identified adjustment and integrated adjustment are motivations for a high degree of autonomy, personal value, and importance to learning, and positive engagement. Subject F, who stated that "going on to higher education," also looked back on those days and said, "I would spend all my free time playing tennis. When I didn't have anyone to practice with, I practiced serving by myself. I guess I was able to push myself harder" (Subject F).

Next, in the subcategory of <observing games>, the importance of watching target competitions and matches in person was demonstrated. Although we could not find any direct previous studies on the effects of watching target tournaments and games, we will discuss them by assuming that "admiration" and "inferiority" are the emotions that arise when watching target tournaments.

In the field of psychology, admiration has been examined under the concept of "identification." And in the field of sports, Uechi (2011) examined the relationship between identification and motivation. It is shown that there is a significant relationship between the intensity of identification and autonomous motivation for exercise and sports. As for feelings of "inferiority," Yamada & Mizuno (2011) showed that it does not necessarily have an inhibitory effect on motivation, but in some cases, they can increase motivation and stimulate efforts to overcome them.

Continuous growth

To achieve a "breakthrough" in tennis, one must continue to improve their competitiveness. However, the process of athletic performance improvement is not linear, and there is a phenomenon called "plateaus," in which skills do not improve even after continued practice, and "slumps," in which performance declines and athletic performance stagnates. Kudo et al. (2011) showed that plateaus and slumps inevitably occur in the process of skill acquisition and improvement. Indeed, even the current world number one in men's tennis, Novak Djokovic, has spoken about experiencing slumps (Davis, 2017). Overcoming these obstacles in the process of maturity and continuing to grow is a major challenge for the athlete.

The subjects were attempting to continuously improve their performance in various ways. First, in the subcategory of <increasing practice>, the importance of lots of practice to improve technique was demonstrated. Chase & Simon (1973) found that it takes more than ten years of practice to achieve outstanding performance. And similar results have been shown in tennis as well (Monsaas, 1985).

Next, in the subcategory of <practicing with better players>, the importance of creating practice opportunities with higher-level players was demonstrated. Ericsson et al. (1993) showed that it is important to challenge oneself with high goals that are slightly beyond one's current level, rather than simply repeating technical exercises, to achieve a deliberate practice. To achieve that, tennis clubs need to implement appropriate governance to ensure that players have a fair opportunity to practice with higher-level players (Hotta & Yamamoto, 2022).

Next, in the subcategory of <recognizing own strengths and weaknesses>, the importance of having a proper self-awareness of one's strengths and weaknesses was demonstrated. Cowden (2017) supports a positive relationship between self-awareness and mental toughness in tennis players, emphasizing the importance of self-awareness.

Next, in the subcategory of <trying new ideas>, the importance of adopting new practice methods and experimenting with new skills was demonstrated. Looking at previous studies examining the effects of standard practice, in which repetitions are performed in a drill-type format, and variable practice, in which a variety of practices are performed, most results support the effectiveness of variable practice (e.g., Kerr & Booth, 1978; Williams & Rodney, 1978; Magil & Reeve, 1978). In tennis as well, Douvis (2015) has demonstrated the effectiveness of variable practice in mastering the forehand drive. Thus, it is important not only to repeat the same practice methods but also to keep changing them.

Next, in the subcategory of <escaping from mistaken beliefs>, the importance of breaking free from false beliefs formed by accumulated knowledge and experience was demonstrated. Such a process has some overlap with conceptual change theory (Chi, 1992). When people learn, they use the structure of existing knowledge to understand and enrich their knowledge. In the subject's case, the subject said, "In practice, we often do offensive practice, such as chance ball practice and volleying practice. In addition, when I watch professional matches, points won by winners tend to be the focus, and that image has stuck in my mind" (Subject E). As stated above, it is considered that the subject had formed the false knowledge that "Offense is the only strategy" (Subject E) from daily practice and experience of watching professional players' matches. However, most points in a tennis match end in errors. It is conceivable that we can move on from false assumptions to the correct perception that "Playing aggressively is not the only strategy, since it is the same as an opponent making an error or me outplaying them" (Subject E).

High performance during games

To achieve a "breakthrough" in tennis, it is important to improve one's skills through practice, but it is equally important to be able to demonstrate one's ability under the pressure of competition. The subject said, "When I was a child, I was the type of person who couldn't show my ability in a match. I have been playing tennis since I was a child, so my technique is good. But something is missing, I can't show my strength" (Subject H).

Baumeister (1984) called pressure a factor or a combination of factors that increase the importance of high performance in a particular situation, and he called the phenomenon in which performance decreases due to "Choking." Various studies have been conducted on choking. Kanamoto et al. (2002) reported that more than 90% of athletes felt pressure during games. Thus, pressure and agitation are factors that prevent athletes from demonstrating their abilities in-game, and overcoming these factors may play an important role in achieving a "breakthrough" in tennis.

The subjects were trying to cope with pressure and choking in various ways and to demonstrate their abilities in games. First, in the subcategory of <match emulation>, the importance of experiencing the same or greater tension in practice as in a game was demonstrated. Oudejans & Pijpers (2010) investigated dart-throwing practices in two groups: one in a "high place with fall hazard" and the other in a "safe low place." In the subsequent performance, the group that had practiced at a high place with fall hazards performed better. It has also been shown that simply imagining tense situations during practice can lead to higher performance under pressure than practicing without doing anything.

Next, in the subcategory of <game repetition>, the importance of participating in many tournaments and becoming accustomed to the game environment was demonstrated. Kanamoto & Yokozawa (2003), which analyzed the factor structure of choking in sports situations, extracted "unfamiliarity of the game situation" as one of the factors. This indicates that "the atmosphere was different from usual" and "it was a situation that we do not experience every day."

Frequent participation in matches may be an effective way to cope with such "unfamiliarity of the game situation."

Next, in the subcategory of <focus on what should be done>, the importance of focusing on the task at hand in a game situation was demonstrated. Hodge and Smith (2014) investigated the target method of choking in the New Zealand national rugby team. As a result, "involved a process/task focus" is mentioned. Thus, it is considered important to concentrate on tasks that can be controlled by oneself, not on the performance of the opponent or the outcome of the match, which are beyond one's control.

Next, in the subcategory of <taking it easy>, the importance of playing in a relaxed state in achieving high performance in the game was demonstrated. Arimitsu (2002) and Higuchi et al. (2007) extracted coping strategies for choking and found that "easy going tolerance," was one of the factors in both cases, indicating that it is effective in reducing choking.

CONCLUSION

The purpose of this study was to reveal hypothetical findings on the factor that enable "breakthroughs" in tennis. Semi-structured interviews were conducted with eight Japanese college tennis players who had experienced a "breakthrough" in the past, and who had a record of being in the top 8 or above in national championships. The interview content was transcribed, and qualitative analysis was conducted. As a result, the following three hypothetical findings were revealed: "maintaining high motivation," "continuous growth," and "high performance during games" are important for enabling "breakthroughs" in tennis.

This suggests that to achieve a "breakthrough," in addition to improving competitive performance, it would be necessary for them to carry out their daily practice and training with strong motivation and to fully demonstrate their competitive ability in competitions. There have been no studies dealing with "breakthroughs" in the field of sports in the past, and those hypothetical findings will be useful for athletes who are aiming for "breakthroughs" and for coaches that support them.

LIMITATIONS AND FUTURE WORK

Since this study was conducted on eight college tennis players who had experienced a "breakthrough" in the past, and who had a record of 8 or better in a national championship, more research needs to be conducted at different levels of competition and different ages to generalize the results. In addition, although this study was conducted only for tennis, it is possible that differences and commonalities among the sports can be found by expanding the scope of the study to other sports in the future.

Since the hypothetical findings revealed in this study are based on interviews and considerations concerning previous studies, we have not been able to verify the causal relationship. Therefore, prospective studies to verify causal relationships and quantitative studies to test hypotheses should be conducted in the future.

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CONFLICT OF INTEREST AND FUNDING

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How can emerging tennis nations survive the tennis arms race? My thoughts through a strategic lens!

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ABSTRACT

This article provides an opinion of the current challenges and unique perspectives experienced by emerging tennis federations. It delves into a comprehensive analysis around strategic development derived from qualitative research involving esteemed individuals in the field, including senior leaders, national coaches, and board members from two distinct nations: Tennis Malaysia and Tennis Ireland. Through this investigative journey, numerous critical challenges have emerged, shedding light on the intricate landscape that smaller federations navigate. The article offers some practical applications for federations to consider when making strategic decisions.

Key words: tennis, talent, strategy.

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INTRODUCTION

The world of professional tennis has become a fierce battleground for success, marked by a remarkable surge in financial investments from National Governing Bodies (NGBs) and National Governing Organizations (NGOs) striving for global recognition and triumph (Houlihan & Zheng, 2013). In essence, sustaining competitiveness, let alone achieving success at the highest echelons, demands a substantial financial commitment. Considering the state of play in tennis, the top 100 rankings for both men and women come from a diverse array of countries (e.g., thirty-four countries in the men's top 100 and thirty-three countries in the women's top 100; ATP, 2022; WTA, 2022). However, when it comes to Grand Slam champions, a select group of countries, including Spain, the USA, and Russia, consistently dominates the scene. While emerging nations have made noteworthy strides in challenging the established order, these successes often hinge on micro-level decisions made by individuals rather than shifts in strategy by the NGB. For instance, Hyeon Chung moved from South Korea to the IMG Academy in Florida as South Korea is not traditionally known for producing top-tier tennis players. This summary article offers a collection of personal perspectives as a past performance director within an emerging nation, opinions on the present landscape and obstacles faced by emerging tennis NGBs. Additionally, it presents some of my recent findings derived from qualitative research (2023) involving prominent figures in the field, such as senior executive leaders, national coaches, and voluntary board members, representing two nations: Tennis Malaysia and Tennis Ireland. This investigation has unveiled a multitude of significant challenges.

WHAT DOES THE RESEARCH TELL US?

Talent Development

Talent development (TD) has been defined as "a multi-faceted process of optimally nurturing athletes over time within a sport-system" (Cobley et al., 2021, p. 8). While the past two decades have witnessed a heightened emphasis on various elements of the TD process in academic discourse (e.g., talent identification, early specialisation vs sampling, coaching, physical conditioning), it can be contended that a substantial portion of this research has overlooked the application of a strategic perspective in shaping TD systems (Taylor, MacNamara, & Taylor, 2022). Put differently, we have accumulated substantial knowledge in specific domains like coaching, sports science and tennis specific training methods. However, there might be an underestimation of the critical importance of strategic planning and execution in the overall development of talent. Another crucial aspect to bear in

mind is that nurturing tennis talent is no longer the exclusive responsibility of NGB's, as private commercial academies are increasingly contributing to the development of the next wave of professional players. In sum, to enhance TD systems in tennis, it might be beneficial to step beyond the confines of the court and coaching methods. Adopting a strategic perspective to assess the overall landscape could provide valuable insights and improvements.

Contextual Factors when developing talent

Strategically, surely emerging tennis nations (defined as nations with high performance systems that have not produced top one hundred ATP or WTA players in the modern era) should just employ coaches or performance directors from successful nations and copy this success? Actually, the process is not that simple, researchers have acknowledged the significance of the environment and the numerous external factors that have the potential to influence TD. For example, Henriksen et al. (2010) have put forth a comprehensive ecological approach to TD, shifting the focus from the athlete to the environment in which their development unfolds. At the core of this approach lies the recognition that macro-level elements such as national culture, the broader sporting culture, and the specific sport environment significantly contribute to athletic success (De Bosscher et al., 2006). Understanding the influence of contextual factors on TD strategy and practice, and how they do so, can be instrumental in shaping decisions when designing strategy. Systems or policies designed and implemented in one context cannot be simply transplanted to another without due consideration of the specific nuances of that environment (De Bosscher et al., 2006). Therefore, for tennis nations aspiring to enhance their performance programs, it's not as straightforward as mimicking the achievements of other countries. Rose (2005) contends that the importation of ideas from one context to another must consider the obstacles and challenges inherent to that particular setting. As a practical example, for a nation like Ireland, it would seem difficult if not impossible to implement a Spanish tennis training system. Clearly, the rain, lack of clay courts and culture of Gaelic sports (traditional Irish sport) would make this a daunting task.

WHAT ARE THE MAIN CHALLENGES FOR EMERGING NATIONS?

In my exploration of the challenges in developing tennis talent in lower performing countries, I engaged in conversations with eleven key figures from Tennis Malaysia and Tennis Ireland. These discussions involved senior executives (including CEOs) national coaches, and voluntary board members, offering a varied perspective. Rather than a formal study paper, consider the following insights as a conversational sharing (combined with personal experience) of significant findings that may resonate with tennis coaches and administrators facing similar challenges.

Signing off the same hymn

Are we all singing on the same hymn sheet? Lack of coherence between the NGB and parents was noted. More specifically, it was regularly discussed how parents and the NGB were often not congruent in their thinking regarding the long-term objectives of TID athletes. This is an example from one national coach.

> *I don't see any NGB strategy; parents are confused. They don't know what they should be doing, and there is much waste in terms of resources.*

The issue of coherence is frequently an issue within sport organisations particularly in the context of multiple coaches working with the same athlete in a single week. In my own observations, this can pose a significant challenge for countries lacking centralised systems. If we draw a parallel to education systems, consider the scenario where parents are told that their child will attend multiple schools or have different teachers within the same week. Such a situation would not be deemed acceptable, yet we often tolerate this when it comes to developing a child's tennis skills.

Coaching market forces

Despite quality coach education systems, many highly qualified, talented performance coaches remain working in recreational elements of the sport. Acquiring a higher-level coaching qualification doesn't necessarily dictate that one must exclusively engage in performance coaching. However, market forces (salary) often play a role in attracting coaches to positions within recreational contexts. It was pointed out that market forces, particularly the income potential for coaches in and recreational tennis (e.g., private recreational lessons, adult groups), resulted in high performance coaches not directing their attention toward coaching young talented players.

> *The problem here is high-performance sports, especially tennis. We do not get money working for the association. It doesn't pay well, so it is better to work outside and do private coaching or groups.*

NGBs strategically positioning and making high performance coaching attractive for highly educated and skilled coaches is a critical aspect that demands thoughtful deliberation to optimize their impact on player development.

Money Money!

Currently, one of the investigated nations has a performance budget of 200K, yes, 200K for a full NGB performance program. In my experience and without access to the exact budgetary information, my estimation is that 200k would just about fund one performance player, coach and support team on tour for one full season. The connection between tennis success and financial resources appears consistent. Although, I would argue that finances are necessary but don't guarantee success. As one experienced executive pointed it out, it's how you spend money not how much you have. For lower performing NGBs such as Tennis Ireland and Tennis Malaysia a targeted approach to performance funding, with the more successful national sports receiving increased funding from the government, makes it increasingly challenging. This was described by one performance director as follows "*The national government only supports the elite sport; world-class tennis is challenging to get support cause of lack of achievement.*"

Seems obvious, but both nations reported a connection between parental wealth and success in tennis. In other words, families who can afford to invest in travel and coaching were perceived to have greater chances of success than children from less affluent backgrounds (cf. Bane et al., 2014).

Does success breed success?

Both nations consistently spoke about "history of success" in a specific sport and in particular how role models could potentially influence the belief of young aspiring athletes about their ability to achieve in tennis. On the other hand, the lack of role models "compared to other countries like Switzerland who have Roger Federer" creates a sense of doubt regarding tennis as a career. Furthermore, the lack of role models was thought to influences parents' decisions regarding committing to performance tennis. More specifically, without an example of someone who had made it, parents are sceptical about the process and often did not commit to performance tennis. This is a quote from one national coach.

> *Not many parents encourage them to join tennis because they don't see the future. Whereas in Thailand, they had Paradorn Srichaphan and were more likely to commit.*

Having developmental players train beside role models was seen as valuable because they tend to imitate what these role models: "I think it is important because the young players tend to emulate and find themselves experimenting, like fashion". Indeed, countries with a consistent flow of skilled tennis players can create a positive domino effect, shaping future generations and potentially gaining a distinct advantage over lower performing nations.

Strategic lens!

Strategy starts with a clearly defined vision! Interestingly, when discussing the strategic plan, no two stakeholders from either country were in agreement about the exact purpose of their high performance strategy. The main difference between board members, coaches and coach educators was whether the program was driven by a performance, participation or both agenda (cf. Collins, et al., 2012). The following are some quotes from the discussions with stakeholders.

> *Top 100 ATP, so they are visible, and kids can see they are doing well; some person on TV doing well. I think we also need to widen the base significantly.*

> *I think if we can grow the numbers of kids that can compete internationally, set a target that we want by having 10-20 playing ITF and able to compete internationally.*

Another crucial factor to note is the relatively short terms of board members. In Ireland and Malaysia, they were between three to five years. In a sport like tennis, where strategic planning takes a significant amount of time, the frequent turnover poses a challenge in maintaining a long-term approach to athlete development. One Malaysian executive described this as follows.

> *In our country policy changes every two years, then three years, they change committee members, but then a new leader, the policy changes, and the previous team.*

Simultaneously, this lack of continuity was perceived to have a ripple effect on staff stability within the TD system. The transient nature of board members can contribute to challenges in maintaining consistent staffing, potentially affecting the overall stability and effectiveness of the system. Clearly, this lack of continuity makes it challenging to apply a long-term approach to athlete development especially in systems without a broader performance agenda.

CONCLUSION

This article emphasises the critical importance of NGBs having a clear strategic understanding of their objectives in TD to ensure coherence throughout the TD system. The absence of a well-defined end product or long-term goals that consider the unique context hinders effective planning. One the other hand, a shared understanding of the overarching purpose enhances integration and resource utilisation (Taylor & Collins, 2021). TD is a strategic decision, for nations with limited resources and smaller talent pools, focusing resources strategically where they can have the most significant impact toward their defined purpose is a logical approach.

To gain an edge, emerging (financially restricted) tennis nations must gain a comprehensive grasp of their operational environment, coupled with well-structured policies and systems that permeate every facet of their TD system. Financial considerations are paramount, and it might be virtually unfeasible for emerging nations to emulate the extensive talent development programs seen in wealthier, more accomplished tennis nations (Seibold, 2010). As a result, nations facing budget limitations may need to prioritize their investments and perhaps cannot cater to all needs and demands. Therefore, rather than keeping as many in the system for as long as possible they may need to support individuals of high potential differentially rather than treating all talent equally in the hope of the cream coming to the top (Martindale et al., 2007).

Coaches play a pivotal role in translating strategy into action and are among the most crucial stakeholders, alongside parents. However, effective tennis coaching is just one (but critical) component of comprehensive player development. Coaches and NGBs must collaborate closely to align strategic elements and implementation programs. Furthermore, incentivising high-performance coaches to work within the system and rewarding their substantial contributions can enhance the overall effectiveness of the development process. Perhaps, in the relentless tennis arms race, strategic planning emerges as the ultimate game-changer for success on and off the court.

PRACTICAL IMPLICATIONS

Certainly, each NGB is unique, and a one-size-fits-all strategy for strategic development is not feasible. Nevertheless, here are five practical recommendations on how emerging nations can enhance their TD systems.

Firstly, NGBs should establish and communicate a clear agreed upon purpose of the TD system. Stakeholders, specifically key NGB staff members and coaches, should be involved in the decision-making process of designing the purpose of the TD system.

Secondly, performance budgets should be tightly aligned with the purpose of the system. This may perhaps mean devising a less linear TD system where investment is focused on a smaller number of athletes and developing highly skilled coaches to work at specific stages of development.

Thirdly, coaches and NGBs need to consider how they can work closely with third parties such as schools and academies (home, abroad) to develop talented athletes. The private sector now offers highly professional training and is capable of providing elements of the pathway that private coaches currently cannot.

Fourthly, coaches play a critical role in TD and NGBs should offer incentives to retain coaches within the performance system. For example, provide flexible contracts, raise their profiles and provide opportunities for coaches to earn additional income. Also, NGBs should consider using technology to provide cost efficient methods of supporting coaches.

Fifth, every country has its own contextual strengths and weaknesses. Coaches and NGBs should consider devising a strategy that allows them to utilise their contextual strengths when developing talent.

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Presumable role of tennis in the evolution of listesic damage: focus on the technical gesture of the forehand in open stance in amateurs

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ABSTRACT

Although there is an individual style by virtue of which each athlete interprets the basic technical gesture by mediating it according to their own biomechanical characteristics, most tennis instructors suggest executing the forehand in open position or, borrowing the term from the English language, in open stance (shoulders parallel to the net) as there is a potential increase in ball speed. All, however, to the detriment of the integrity of the spinal tract, especially in genetically and anatomically predisposed subjects (Lisi, 2018). Without wanting to go into the merits of professional tennis, the Authors advise - in those who approach racket sport as an amateur without ambitions of excellence - the use of the traditional closed position (shoulders perpendicular to the net) or, at least, a semi-open stance as it is sufficient to limit any harmful consequences at the level of the spine and to maintain one's competitive performance (Lisi, 2018).

Key words: spine, forehand, open stance, closed stance, semi-open stance.

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INTRODUCTION

Spine is substantially made up of a sequence of bone segments connected to each other by ligament, capsular and tendon structures which make it, albeit in a different way in the various sections that compose it, mobile but stable in the healthy subject. In subjects who practice sports (specifically tennis players) they are required, in the context of a dynamic of a cybernetic nature, where the body learns and memorizes motor sequences, kinesthetic adaptations and continuously adapted to the instantaneous motor needs required by the gesture.

From this point of view, it is important that the athlete enjoys continuous monitoring by the medical-rehabilitation team. The maintenance of physiological curves, capable of following harmonic mobilization dynamics, integrated by the individual segments, will also serve to prevent the onset of symptoms that can also lead to total blockage of activity. The spine of young professional tennis players with no symptoms related to vertebral column pathologies was studied using magnetic resonance imaging. It emerged that only in 4% there were no pathological alterations of the spine (Rajeswaran et al., 2014).

These observations suggest that the stresses on the spine during the performance of tennis are extremely intense and make technical preparation an essential element of tennis practice proper (Lisi, 2018). During the execution of the basic strokes of tennis, the kinematics of the body segments has allowed to obtain important indications of practical utility

(Elliott, Baxter & Besier, 1999; Elliott, Takahashi & Noffal, 1997; Elliott, Overheu & Marsh, 1988; Kibler, 2004; Knudson, 1990). First of all, the fundamental role of internal rotation of the arm in the forehand was highlighted, significantly influencing its execution in both beginner and advanced level players.

Functionally, the rotator cuff muscles (particularly the joint action of the supraspinatus and subscapularis) must accelerate the upper limb to impact and continue their action before the antagonists contract eccentrically to decelerate the rotation in the follow-through phase (terminal phase of the technical gesture). The structural difference of the two muscle groups

(the internal rotators smaller than the external ones) requires a reconsideration of the specific training phases in order to avoid injuries or more or less disabling pathologies.

THE VARIOUS TYPES OF EXECUTION OF THE FOREHAND

The use of the open stance (Figure 1C), if it is not possible to adopt the traditional closed stance (Figure 1A) (shoulders perpendicular to the net) where a plastic evolution of a wider and slower movement is evident, does not allow adequate impulse generation at the trunk level and effective use of the lower limbs. This particular technical setting, in fact, by reducing the amplitude of the torsions of the trunk, places a limitation on the release of the force. The impossibility of performing rotations around the vertical axis reduces the ability to impose the right acceleration on the racket with an effective and balanced contribution from all body segments.

And this happens above all when the left lower limb (in a right-handed person), at the moment of loading the shot, is extended rather than bent and twisted. Again, although the movement of the body at the baseline is facilitated and the ball - from the frontal position - better visualized and perceived, the tennis player, "working only with the arm" as they say in tennis jargon, is required to accelerate the action of the limb dominant top to give the ball the classic forward rotation (top spin).

Among other things, the tennis player - who performs the forehand in an open stance (Figure 1C) - engages the lumbar spine in a right lateral inclination, which, although it is almost analogous to that shown in the tennis player in Figure 1A, requires a significantly right-hand rotation greater; in fact, in the tennis player in Figure 1A (closed stance), the right lateral portion of the lumbar spine and the right hemipelvis are already further back and therefore require a less demanding rotational movement for the capsule-ligament structures. It follows in our personal opinion that the tennis player in Figure 1C subjects the right vertebral hemiarch of the last lumbar vertebrae to a greater stressful insult on the isthmic area which, if frequently reiterated over time, could result in, among other things, a duration fracture (spondylolysis right isthmic) [Lisi, 2018].

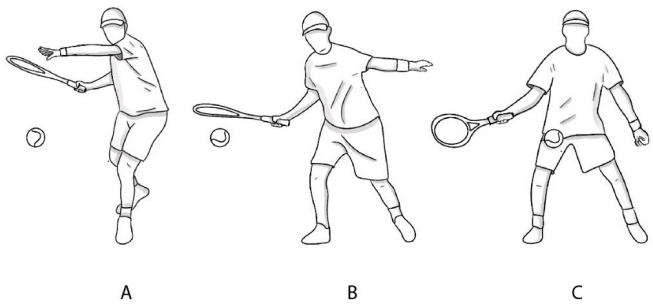

Figure 1. *A. Closed stance; B. Semi-open stance; C. Open stance.*

TENNIS AND SPONDYLOLYSIS

Spondylolysis, frequent in athletes, is the loss of continuity at the level of the isthmus between the upper and lower articular facet. Sometimes it evolves towards listesis, affecting the practice of sporting activity.

The causes are varied and may have a genetic or mechanical root (associated with morphotypes with altered biomechanics from excess sacral tilt or scoliotic deviations), possibly associated, quite rarely, with subsequent traumatic events. Advancing age shows an additional cause in joint degeneration. Elective instrumental examination to detect the alteration is radiographic. CT and MRI are rarely needed to specify the anatomical picture.

Lysis is often detected as early as in the young, more often in males, due to the onset of pain: evolution in the pubertal period is high. In sportsmen and women, as we have said, it causes a slowdown or halt in the continuation of activity with the related consequences, especially in young competitive athletes, at the psychological level. In these cases, it is appropriate for the sportsman to be referred to a multidisciplinary team that can assess whether and how to continue trainig. This is particularly true in tennis, where the risk of progression of symptoms is higher due to the constant engagement of the spine.

TENNIS AND SPONDYLOLISTHESIS

Tennis, not unlike other sports, can be the underlying element of the symptomatology and possible listhesis. In addition to being supported by numerous researches on the incidence of spondylolisthesis in competitive and non-competitive sportsmen (Rossi, 1978; Hoshina, 1980; Ichinawa et al., 1982; Jackson, Wiltse & Cirinciole, 1976; Kotani et al., 1971; Kono, Hayashi & Nasha-Hara, 1975) in support of the above assertion, the results of a study conducted by Takaaki Ikata, particularly prolific in dealing with issues relating to vertebral instability (Ikata et al., 1996). concluded that «[...] in an immature spine, the advanced stage of a defect of the interarticular portion is a risk factor for the onset of the often mentioned spondylolisthesis» (Ikata et al., 1996).

Among other things, and more recently, Rajeswaran and colleagues investigated the MRIs of 98 asymptomatic elite young tennis players (51 men and 47 women) with an average age of 18 years, highlighting anomalies in the pars interarticularis in 29.6% of subjects examined, with spondylolisthesis in 5.1% of players (Rajeswaran et al., 2014). Men had a higher prevalence than women (Rajeswaran, 2014). Alyas and colleagues, in a similar study, found lesions to the pars articularis, predominantly in level L5 (9/10-L5, 1/10-L4), in 9 tennis players out of a total of 33 subjects recruited for the study (Alyas, Turner & Connell, 2007).

The minute reconstruction effectively sanctions the dangerousness of the sport of tennis, i.e. a sport that stresses the spine in hyperextension (service) and extension and forced rotation (forehand)[Lisi, 2018]. Over the years, the paroxysmal obsession, aimed at achievement of the result as an end in itself, has in fact produced considerable changes in the execution methods of a certain technical gesture. See the service and the law, which have become increasingly explosive and decisive. In the past, the forehand stroke was made using the traditional closed stance (Figure 1A). In this position, the transfer of energy evolves from the feet to the trunk through the ascending twist of the legs, and from the trunk to the shoulders until it reaches the racket (Lisi, 2018).

Many authoritative specialists, including Saal and Ruiz-Cotorro, believe that this technical approach significantly reduces the stresses at the level of the pars interarticularis (Saal, 1996; Ruiz-Cotorro et al., 2006) probably proving to

be safer from a biomechanical point of view than modern methods of interpretation of the fundamental where the tennis player impacts the ball frontally on the net (open stance - Figure 1C). In the latter case, there is in our opinion a potential increase in the speed of the ball at the expense of the integrity of the spine, especially in genetically and anatomically predisposed subjects (Lisi, 2018). However, the onset of this pathology is absolutely subjective and correlated to multiple factors which, both acting alone and jointly, can determine the damage (Denard et al., 2010; Bhalla & Bono, 2019). It is possible to act preventively on some of these contributing causes, while other etiological aspects are not very editable.

If in fact the closure of the growth plates at this level occurs between the ages of 7 and 12 and it is therefore possible to focus attention on the onset and evolution of spine-related problems in this particular age range, it is equally clear that a further area of action is to be framed in the training methods, in particular as regards intensity and frequency, bearing in mind that the right exercise, performed by extension and forced rotation of the rachis, causes an overload of the posterior arch of the vertebra (Ruiz-Cotorro et al., 2006). Likely, such occurrence is expressed in predisposed subjects, in which functional overload induces stress pathology (Ruiz-Cotorro et al., 2006; Denard et al., 2010). In fact, like all stress fractures, the same training loads may or may not determine the problem in different types of subjects as a function of notable variables: such as muscular conditions, equipment, personal anatomical conditions and, last but not least, predispositions on a hereditary basis (Albanese & Pizzutillo, 1982; Friberg, 1987; Newman, 1963; Wynne-Davies & Scots, 1979).

In some cases, when the gesture in question is perpetrated, under the action of load and muscle traction, the vertebral body, pedicles and upper articular processes slide progressively forward; while the lower articular apophyses, the laminae and the spinous process remain in place, giving rise to the olisthesis. Therefore, the aetiopathological connection between these pathologies and the typical strokes of tennis, in particular the forehand, is found not in a precise traumatic event, but in an absolutely progressive triggering gesture on a substrate of multiple predisposing factors (Lisi, 2018; Ruiz-Cotorro et al., 2006). Basically if genetic aspects, at least at the moment, are scarcely modifiable, there is a wide field of action involving the techniques of preparation and management of the athletic gesture, implying the need for a constant clinical and technical follow-up of the athlete, done constant in professionals but still very far from reaching in amateurs, where the assistance of a multidisciplinary team (physiotherapist, psychologist, doctor) who collaborates with trainers is almost always absent and constantly neglected in the occasional tennis player.

PRACTICAL APPLICATIONS

Based on the review of the Literature and our personal practical and theoretical-clinical experience, the evidence is, in our opinion, that amateur players should use closed positions to hit forehand. This technique may lead to better results related to the target of this particular category of players, avoiding physical damage that can lead to a long stop in sport activities.

In this regard, instructors are invited to focus on some technical aspects, which are often underestimated: among these, the lack of use of the non-dominant arm (Figure 2B). it is evident how the correct use of the opposite limb improves the acquisition of the same technique in closed support, since it helps to rotate the trunk and, therefore, to position oneself perpendicular to the net (Figure 2A).

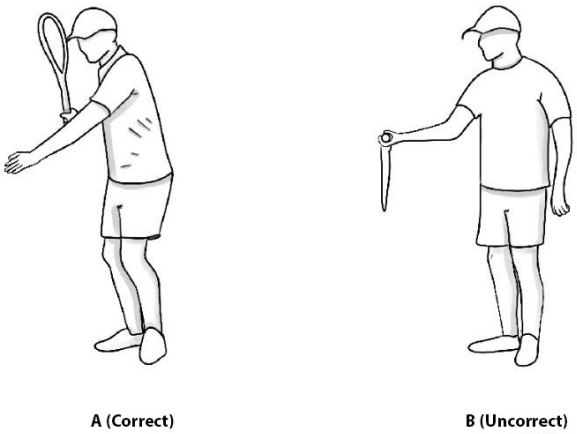

Figure 2. *A. Correct forehand closed stance; B. Uncorrect tennis forehand closed stance.*

CONCLUSIONS

When we talk about tennis we resort and refer without delay to the typically professional activity. That tennis, in other words, characterized by actions of short and very short duration (Gallozzi, 1992). But tennis, in the most global sense of the term, is also that of the Sunday amateur - who hopes to be able to prevail over the Club member without endangering his physical safety, dribbling for hours on one of the many clay courts of the suburbs - or that of our veterans. Who, although they don't express the same excellence in terms of performance as the more paid and noble colleagues on the professional Tour, still manage to be satisfied and satisfied. In the present work, the general principles and the theoretical premises of reference, therefore, find their practical justification in amateur tennis players, junior and senior (veterans), also in consideration of their lower speed of play compared to that of their professional colleagues. In fact, the latter often resort to the open position precisely because of the speed of play which, being particularly high, leaves little time to execute a given shot: the tennis player thus assumes the position deemed most convenient.

More convenient, sure, but not always the safest in terms of physical well-being. If, as far as professional tennis players are concerned, it is not at all unusual for players to be forced to change pitches within a week or two, given that tournaments take place in numerous locations around the world and on different surfaces (passing, for example, from the red clay of Roland Garros and the European tournaments to the grass courts such as those of Queen's and the German Halle) even the amateur tennis player can find himself, by chance or for contingent needs due to the availability of playing fields or invitations by friends who frequent different clubs, playing on different surfaces (rarely grass, but very often clay or synthetic surfaces of various kinds) and consequently

different responses to player interaction (Lisi, 2009; Lisi, 2016). These sudden changes, due in the first case to an increasingly dense tennis calendar and in the second to chance, often associated with a dangerous discontinuity in the activity, and the impossibility of adapting in such a short time to this or that specific surface, can cause, if not more or less disabling injuries, algic symptoms of various kinds affecting the musculoskeletal system (Lisi, 2016; Lisi, 2018). Furthermore, it is necessary to remember that in the tennis practice of amateurs, juniors and overs, and in their interaction and integration with different terrains, the playing technique and physical preparation (often in this case poorly maintained and balanced) are integral and predominant factors in assessing the risk of possible damage.

There is no doubt that a tennis player who has reached a certain age, or an athlete who occasionally practices the sport of tennis, is required to strictly comply with some general rules in order to be able to continue his sporting activity without risk. But an accurate technical setting of the basic strokes is equally important. The veteran and the amateur tennis player (or the Sunday sports lover), assuming at least the partially open position (semi-open stance – Figure 1B), will thus be able to practice the sport less tiringly, to preserve the neuro-muscular system- skeletal system, reducing the risk of contracting injuries and, at the same time, improving performance on the court (Lisi, 2018).

CONFLICT OF INTEREST AND FUNDING

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What can artificial intelligence do for tennis?

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ABSTRACT

In the current era of Artificial Intelligence, we are witnessing how this technology is revolutionizing the world of sports. Through a review of the main Machine Learning research in tennis over the last decade, players, coaches, and fitness trainers can discover new proposals to improve and personalize training sessions, enhance player effectiveness, and optimize decision-making during competition.

Key words: machine learning, performance analysis, artificial intelligence, research.

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INTRODUCTION

In our days, it is increasingly common to talk about the terms Artificial Intelligence (AI) or Machine Learning (ML) in the sports context, but what do they mean? How do they work? What studies have been carried out? What applications can they have in the world of tennis? The term AI was first used by John McCarthy in 1956, who later proposed the following definition: "It is the science and engineering of creating intelligent machines, especially intelligent computer programs. It is related to the task of using computers to understand human intelligence, but AI does not have to be limited to biologically observable methods." In other words, AI is characterized by the combination of computer science and data analysis to address complex problems (McCarthy, 2004). Russell and Norvig (2010) contributed with a renewed approach to the study of AI, classifying computer systems according to their ability to reason and act. ML, is a subset of AI conceptualized initially by Arthur Samuel in 1959, which allows computers to improve in specific tasks without using explicit programming. Essentially, ML uses computer algorithms to analyze data and learn from it through experience, classifying or predicting a certain event (Mitchell, 1997). The development of an ML model consists of the following parts:

- Selection and preparation of the dataset
- Choice of algorithm or set of algorithms
- Model training
- Use and improvement of the model

Deep Learning (DL) constitutes a subset within the field of Machine Learning (ML). Among all DL algorithms, neural networks stand out above all, which emulate the biological neurons of the human being, simplifying their operation and focusing on information processing. These Artificial Neural Networks (ANNs) have shown great effectiveness in solving classification, prediction, optimization, or pattern recognition problems (Stanko, 2020; Thakur & Konde, 2021).

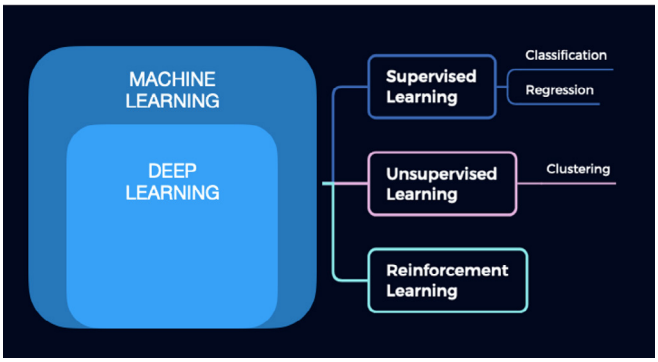

Figure 1.

ML IN TENNIS

In the last two decades, technology has experienced an unstoppable advance, manifesting itself both in everyday life and in the sports field. The collection of data and its quality, through systems such as Tracking or Tagging, has caused a significant change in the landscape of professional sports and in Sports Science research. The emergence of 'big data' in professional tennis, largely facilitated by the incorporation of Hawk-Eye (HE) in 2006, has allowed for more sophisticated analysis through the application of ML techniques and opened up new research approaches associated with tennis (Chase, 2020). In recent years, there has been a significant increase in the number of scientific articles that employ ML techniques in the field of tennis. This increase reflects the recognition of ML's effectiveness in addressing specific challenges in the tennis context, providing new perspectives and innovative approaches to analyzing data, improving players' performance, and better understanding game patterns. Below, we will briefly review different studies that have contributed to this in recent years.

The serve has become a fundamental shot in modern tennis, as evidenced by match statistics in the men's category. Players initiate the point with it and seek to take control of the game. Wei et al. (2015) analyzed 7,050 serves using Hawk-Eye (HE) data during three editions of the Australian Open (2012-2014) to predict the most likely serve of a player in a given context. The aim of the study was to provide coaches and players with a useful tool for match preparation against a specific opponent, which could even be used during the match in a given situation.

The following study also focused on the serve. Data from HE on 262,596 points from Grand Slam (GS), ATP, and WTA tournaments between 2003 and 2008 were used. A comprehensive analysis of first and second serves was conducted, evaluating their importance based on surface, speed, direction, and spin applied (Mecheri et al., 2016). It was one of the first studies to handle a huge amount of data and delve into the serve, highlighting the importance of taking a comprehensive approach to it by providing clear and concise performance indicators in both men's and women's individual tennis. This can provide coaches with indispensable material to prepare their training sessions most efficiently.

In 2017, Whiteside and Reid conducted a study on the most determining characteristics a serve should have to achieve an ace. For this, they analyzed 25,680 first serves from 151 matches in the men's draw of the Australian Open played between 2012 and 2015. The serve angle and bounce distance to the line were decisive in achieving a direct ace, and this information can be crucial for players both to plan training sessions more selectively and to improve decision-making in matches at critical moments.

Another study, this time by Kovalchik and Reid (2018), analyzed the serves, rallies, and points of the Australian Open between 2015 and 2017. The data were collected through the Hawk-Eye system, with a total of 448,159 shots in over 400 matches between men and women. They identified 13 different types of serves in men, while in women, 17 types were identified on the Advantage side and 15 on the Deuce side. They also provided a comprehensive taxonomy of the different types of tennis shots in the male and female individual categories. This information can provide coaches with a very powerful tool to prepare their players more specifically and representatively.

Reading the ball to try to anticipate the opponent is crucial during exchanges in matches. For this reason, Shimizu et al. (2019) proposed a novel method to predict the direction of a player's next shot based on their posture and position prior to hitting the ball. Players could conduct video analysis sessions to study their opponent to predict their shots in a given context in the preparation of their matches, as is often done in other sports.

Stan Wawrinka, after defeating David Ferrer in the 2014 Monte Carlo semifinals, stated: "I know that when I move well, I can dictate the rhythm of the game." The following study by Giles et al. (2020) identified and classified medium and high-intensity change of direction (COD) movements in professional male and female tennis. The speed, distance covered, change of inclination, and acceleration of both male and female players were examined to identify the significant physical demands of such a dynamic sport as tennis. This data is crucial for physical trainers and athletes, as it provides valuable information to improve physical preparation during training sessions, which can translate into more optimal performance in competition.

The volley is another shot that has been studied in depth in tennis research. Thus, Martinez-Gallego et al. (2021) studied the different types of volleys that occur in men's and women's doubles matches belonging to the Davis Cup and the Billie Jean King Cup, respectively. The results showed 7 different types of volleys in the men's category, while only 4 different types were obtained in the women's category. These findings can be very useful, as the volley is a very specific tennis shot, knowing the different types of volleys that occur during competition can make a difference during the game.

The return has also been the subject of study using ML methodology. Kovalchik and Albert (2022) analyzed 142,803 points belonging to 141 male professional players between the years 2018 and 2020. The results showed six different return zones for first serves and six different zones for second serves. Similar to the previous study on volleys, this information can be crucial for planning and specific preparation based on the different types of returns.

As previously mentioned, the serve is a decisive shot in modern tennis in both singles and doubles disciplines. Therefore, Vives et al. (2023) analyzed a total of 14,146 first serves from Davis Cup ties played between 2010 and 2019. The angle of the serve and the distance of the bounce to the sideline were key factors in achieving a direct ace, far more than speed. Hence, players can have very specific parameters to increase their effectiveness on first serves, thus optimizing decision-making for servers in crucial moments of the match.

Lastly, Zhou and Liu (2024) examined the preference for the type of stance in male professional players. The methodology included data analysis from the Australian Open using Bayesian network models, highlighting the predominance of open and semi-open stances in forehand strokes, and the closed stance in two-handed backhand strokes. The results obtained showed that the player's position and the ball's bounce zone determined the player's choice of stance type. Therefore, coaches could undertake much more defined work in hitting zones during training sessions.

PRACTICAL APPLICATIONS

As we have observed in the previous section, ML has been developing in the field of modern tennis research. The results of the different studies provide very concise and detailed information in different areas of the game, ranging from specific shots such as the serve, return, or volley, to predicting the direction of the next shot, the type of stance, or the physical demands during competition. This information can be very interesting for optimizing and personalizing training programs by coaches and trainers, maximizing the effectiveness of players, and improving decision-making during matches. Given that high-performance matches are increasingly closely contested, often it is the small details that can make the difference between a victory and a defeat.

Table 1. *Summary of the main ML studies in tennis.*

AUTHOR(S)	YEAR	SAMPLE	DATA	AREA OF STUDY
WEI ET AL.	2015	4.758 1º SERVES, 2.292 2º SERVES	HAWK EYE	SERVE
MECHERI ET AL.	2016	262.596 SERVES	HAWK EYE	SERVE
WHITESIDE & REID	2017	25.680 1º SERVES	HAWK EYE	DIRECT SERVE
KOVALCHIK & REID	2018	270.023 SHOTS MEN 178.136 SHOTS WOMEN	HAWK EYE	SHOT TAXONOMY
SHIMIZU ET AL.	2019	1 VIDEO, 1 MATCH	YOUTUBE	SHOT PREDICTION
GILES ET AL.	2020	9 MEN , 10 WOMEN, 1710 COD	HAWK EYE	DIRECTION CHANGE
MARTINEZ-GALLEGO ET AL.	2021	24.982 VOLLEYS, 142 MATCHES	HAWK EYE	VOLLEY IN DOBLES
KOVALCHIK & ALBERT	2022	142.803 POINTS, 1.334 MATCHES	TRACKING DATA	RETURN
VIVES ET AL.	2023	14.146 1º SERVES	HAWK EYE	1º SERVE IN DOUBLES
ZHOU ET AL.	2024	36 PLAYERS, 42 MATCHES	KINOVEA	TYPES OF STANCES

CONCLUSIONS

The implementation of tracking data and new technologies in professional tennis has allowed for more detailed and in-depth analysis of the spatiotemporal characteristics of the game. This evolution has changed the way data is approached, leading to an increase in the number of studies employing machine learning (ML) or deep learning (DL) techniques. These trends indicate a significant shift in how performance in tennis is understood and analyzed, suggesting a promising future for the application of advanced analytical methods in this sport.

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Analysis of serve and first shot sequences in U-12 and U-14 tennis players

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ABSTRACT

Stroke sequence analysis in junior tennis helps identify patterns of play and could help improve the performance of players in formative stages. The purpose of the study was to analyze the sequences of serve and third shot (serve +1) in elite youth tennis, in the men's U-12 and U-14 categories. The direction of the serve, the position of the players when executing the third stroke and the direction in which they send the ball were evaluated. It was found that U-12 players have less effectiveness in second serves. The location of the shots varies depending on the category and the situation of the game. The importance of training service sequences and first shots to improve performance in junior tennis is highlighted.

Key words: notational analysis, junior tennis,stroke sequences, sports performance.

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INTRODUCTION

In tennis, various game situations can be analysed through notational analysis, which has become particularly important for tactical assessment in sport (Gillet et al., 2009). This methodology provides objective and accurate data that is essential for coaches to provide effective feedback to players and improve their performance (Martínez-Gallego, 2015).

Notational analysis provides significant details about tennis dynamics, highlighting that most points are decided in the first point rallies (Carboch et al., 2018; Fitzpatrick et al., 2019; Klaus et al., 2017). These findings underscore the critical importance of a powerful serve and dominating from the first shots. The first serve, due to its high speed, generates a significant advantage, forcing the returner to do it outside the court and creating open spaces for the next shot, as observed (Kovalchik & Reid, 2017; Reid et al., 2016). This results in the percentage of points won on the first serve being significantly higher than those won on the second serve (Gillet et al., 2009).

In the specific case of junior tennis players, previous studies indicate that there are gender differences in the execution of the serve, influenced by age and experience. More experienced players tend to direct their serves towards the corners, while more novices prefer to direct them towards the opponent's body (Hizan et al., 2015). In addition, the probability of winning points on the first serve is significantly higher (55.9%) than on the second serve (42.9%), and it is more common for junior players to make errors on the third shot rather than achieve a winning point (Klaus et al., 2017). These observations reinforce the importance of effectively training the sequence between the serve and the first shots.

In the practice of serve and return, elite junior players find fewer opportunities to execute the third (serve +1) and fourth stroke (return +1) in training (13% and 18%, respectively) compared to actual matches (60% and 61%, respectively), revealing statistically significant differences (Krause et al., 2019). In addition, it was found that, during training, when players were tasked only with serving, a reduction in the number of serves that fell inside was observed, compared to the situation where a third stroke was added after the return (Krause et al., 2019). This shows the importance of understanding and training these sequences of the serve and first shots during training, which have been shown to be critical aspects that largely define the performance of tennis players.

Evaluation and monitoring of performance in junior tennis is crucial for the effective development of players in training (Kolman et al. 2021). It is critical that training programs are designed to fit the specific needs of each stage of youth development. The differences between junior and professional level are significant and well-documented (Kovalchik & Reid, 2017), underscoring the importance of adapting training methods. Therefore, the main objective of this study was to describe and establish whether there were differences in the sequences of strokes of U-12 and U-14 players in service situations, including the direction of the serve, the position of the players when executing the third shot and the direction in which they send the ball. The results obtained provide valuable information to optimize the preparation of young tennis players for the competition.

METHODS AND PROCEDURES

Sample

The sample consisted of 8 matches in total, 4 men's matches of each category, in which 6 U-12 players and 7 U-14 players participated. A total of 438 points were analysed for the U-14 category and 449 points for the U-12 category, extracted

from the Petit As and Open Super 12 Auray tournaments, respectively. All players evaluated were right-handed and matches were played on indoor hard courts, starting with the quarterfinals.

Procedure

Using the Kinovea program (0.9.5-x64) the court was divided into different zones (see figure 1), which allowed both the position of the players and the bounce of the ball to be recorded. The encoder followed the recommendations described in previous studies (Hizan et al., 2010, 2015), to ensure that the locations of the ball bounce for each of the strokes were coded as accurately as possible.

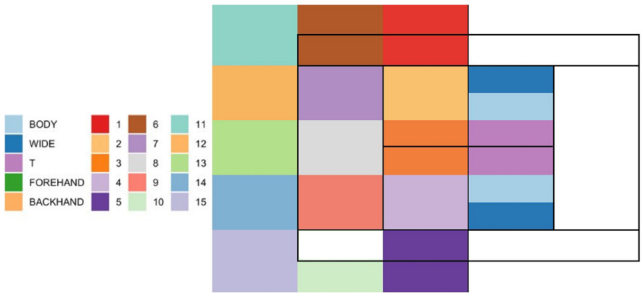

Figure 1. *Areas of the court.*

The data were recorded in an Excel spreadsheet with the sequentiality of the behaviors. General information related to the data of the players and the score was recorded. In addition, for each point the result of the same and the number of strokes were recorded. To analyze the sequences, information about the serve was recorded, including the type of serve (first and second serve), the side of the court (Equals or Advantage side), the direction of the serve (Open, Body and T), and information about the third stroke (serve +1), including the hitting zone and place of bounce of the ball after the shot.

Statistical analysis

Statistical analysis was performed using RStudio software version 1.3.959 for Mac. Descriptive data is reported through percentages according to category. Using the "TramineR" package, sequence analysis techniques were applied to explore and contrast the sequences employed by the tennis players. This process included three distinct approaches: comparing sequences between categories, identifying common patterns in each category, and analyzing the most frequent states. These analyses were categorized according to the type of serve (first or second) and the side of the court (deuce side or advantage side).

To quantify the differences and similarities between the sequences, dissimilarity analysis was employed, specifically using the Hamming distance. This metric evaluates sequences and records the number of positions in which sequences differ, that is, the number of mismatched elements in sequences. Based on the dissimilarity matrix generated, the discrepancy between the categories was analyzed, determining a statistical significance level of $p \leq 0.05$.

RESULTS

Table 1 shows the descriptive variables of the service and the duration of the points. As can be seen, both categories show similar values both in the number of serves played and in those won with the first serve. However, there is a notable disparity in the percentage of second serves won, particularly evident in the players of the U-12 category, who barely achieve 34% effectiveness in the points played against 56% of the U-14s. In addition, it highlights how short points are the most common in matches in both categories.

Table 1

Descriptive Match Variables.

Variables	U-12	U-14
1st serve in (%)	62%	62%
1st serve won (%)	56%	59%
2nd serve won (%)	34%	56%
Double faults (per match)	6.25	4.25 pm
Points of 4 or fewer strokes (%)	46%	50%

Deuce side analysis

Table 2 shows the most frequent situations for each of the variables in the sequence on the deuce side, for both the first and second serves in both categories.

Table 2
Most frequent situations for each of the variables in the sequence.

Category	Service	Service Direction	3rd Shot	3rd Shot Zone	3rd Shot Bounce
U-12	1	Body T Wide	Forehand	Behind baseline: - Center	Deep: -Backhand -Error
	2	Body T	Forehand Return Error	Behind baseline: -Right -Center	Deep: -Center
U-14	1	T Wide	Forehand Return Error	Behind baseline: -Center Inside the court: -Center	Deep: -Backhand
	2	-Body -Wide -T -Double Fault	Forehand Backhand	Behind baseline: -Right -Center -Left	Deep: -Backhand -Forehand -Center

Most frequent sequences

First Service:

U-12 category: players send their serves in all three possible directions, without having a dominant area, the third shot was primarily a forehand being behind the baseline in the central area, playing deep to the opponent's backhand, or making a mistake (see Figure 2).

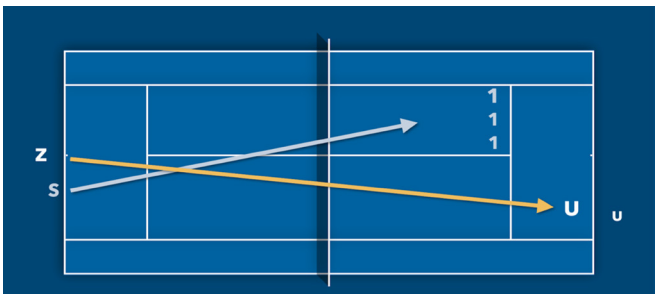

Figure 2. *Stroke sequence most commonly used in U-12. The larger the number or letter, the more shots recorded in that area. Note: S=server; 1= Serve placement; Z=Impact zone of 3rd shot; U= 3rd shot placement.*

U-14 category: they make serves mostly towards the T, followed by wide serves. In addition, his first shot after serving tends to be a forehand impacted from the central areas of the back of the court, playing the deep shot to the opponent's backhand. Also, there are return mistakes, which causes the completion of the point before the third stroke (see Figure 3).

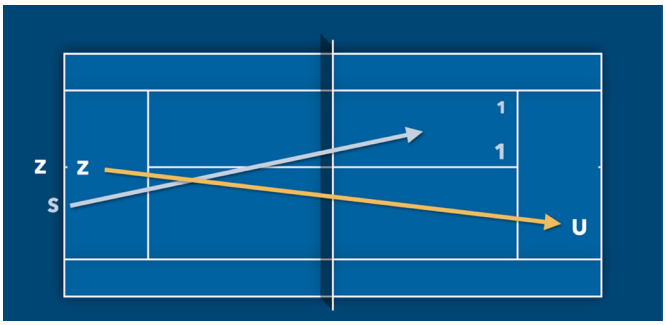

Figure 3. *Stroke sequence most commonly used in U-14s. The larger the number or letter, the more shots recorded in that area. Note: S=server; 1= Serve placement; Z=Impact zone of 3rd shot; U= 3rd shot placement.*

Second Service:

U-12 category: they mostly execute serves to the Body direction and then to the T, their third shot is a forehand impacted outside the court, in the central or right area, playing deep from the center to the center of the opponent. In addition, there are return mistakes, which causes the point to be completed before the third stroke (see Figure 4).

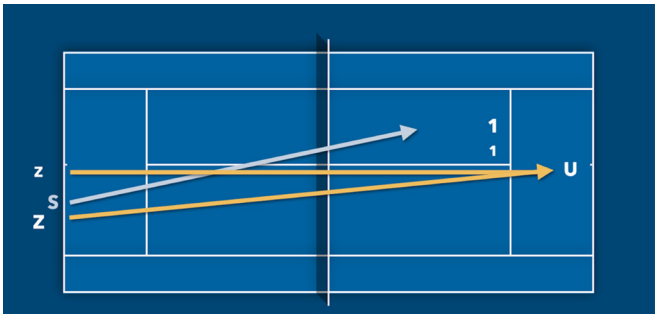

Figure 4. *Stroke sequence most commonly used in U-12. The larger the number or letter, the more shots recorded in that area. Note: S=server; 1= Serve placement; Z=Impact zone of 3rd shot; U= 3rd shot placement.*

U-14 category: they serve more times to the Body, but also in the other two possible options, the third stroke can be a forehand or backhand, although more forehands are given. Their location at the time of impact is behind the baseline in the right zone primarily, but also in the central zone and less so in the left zone, playing deep balls in all directions (see figure 5).

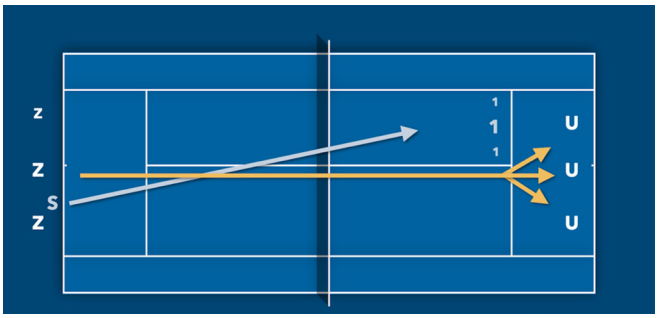

Figure 5. *Stroke sequence most commonly used in U-14s. The larger the number or letter, the more shots recorded in that area. Note: S=server; 1= Serve placement; Z=Impact zone of 3rd shot; U= 3rd shot placement.*

Advantage side analysis

Table 3 shows the sequences used on the advantage side for both the first and second serves.

Table 3

Sequence of Points Played on the Advantage Side.

Category	Service	Service Direction	3rd Shot	3rd Shot Zone	3rd Shot Bounce
U-12	1	Wide Body T	Forehand Backhand	Behind the baseline: -Center -Left Inside the court: -Center -Left	Deep: -Forehand -Center -Backhand
	2	Body Double Fault	Backhand Forehand Return Error	Behind the baseline: -Left (open)	Deep: -Center
U-14	1	Wide	Forehand Return Error	Inside the court: -Center -Left Behind the baseline: - Center -Left	Deep: -Backhand -Center
	2	Body Wide	Backhand Forehand Return Error	Behind baseline: -Left	Deep: -Center

Most frequent sequences

First Service:

U-12 category: their serves are directed in all three possible directions, the third shot can be forhand or backhand, impacting from the central or left areas inside but especially outside the court, executing a deep shot in all directions, although a higher percentage to the forehand of the opponent (see Figure 6).

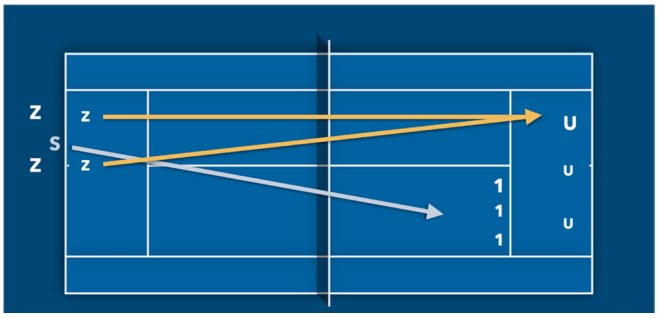

Figure 6. *Stroke sequence most commonly used in U-12. The larger the number or letter, the more shots recorded in that area. Note: S=server; 1= Serve placement; Z=Impact zone of 3rd shot; U= 3rd shot placement.*

U-14 category: they serve wide, the third shot is a forehand, impacted from the central or left position on the court, playing the deep shot to the opponent's backhand. Also, there are missed returns, so they don't play the third stroke (see Figure 7).

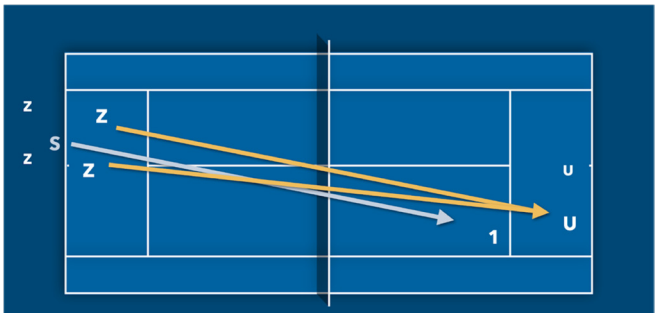

Figure 7. *Stroke sequence most commonly used in U-14s. The larger the number or letter, the more shots recorded in that area. Note: S=server; 1= Serve placement; Z=Impact zone of 3rd shot; U= 3rd shot placement.*

Second Service:

U-12 category: they serve to the Body direction, their third shot is mostly a backhand, followed by forehand or they do not play it because of the opponent's failed returns, the location of the impact is in open areas on the left side and outside the court, playing with this shot deep balls to the center (see figure 8). In addition, they commit double faults.

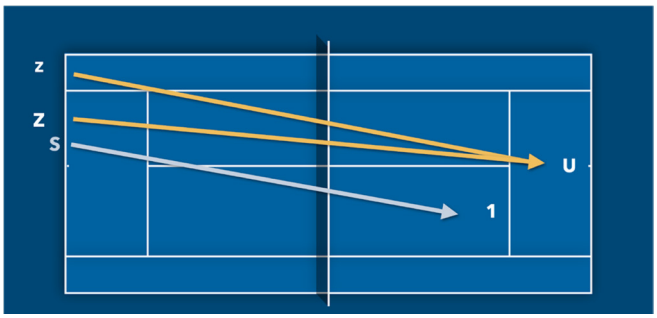

Figure 8. *Stroke sequence most commonly used in U-12. The larger the number or letter, the more shots recorded in that area. Note: S=server; 1= Serve placement; Z=Impact zone of 3rd shot; U= 3rd shot placement.*

U-14 category: they serve both to ide and to the body, the third shot can be a forehand or backhand, although there are more backhands or they do not play it because of the opponent's failed returns, their location at the time of impact is outside the court in the left area, to play deep balls to the center (see figure 9).

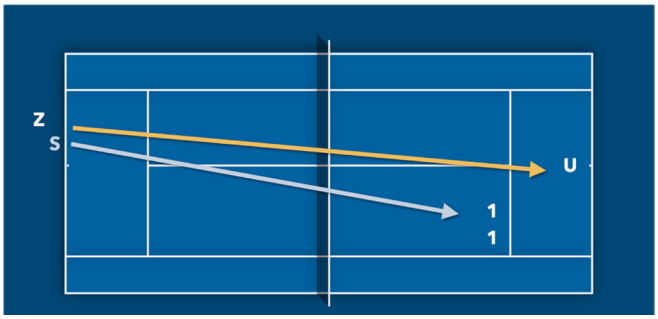

Figure 9. *Stroke sequence most commonly used in U-14s. The larger the number or letter, the more shots recorded in that area. Note: S=server; 1= Serve placement; Z=Impact zone of 3rd shot; U= 3rd shot placement.*

DISCUSSION

The aim of the study was to describe and establish whether there were differences in the sequences of strokes of U-12 and U-14 players in service situations, including the direction of the serve, the position of the players when executing the third shot and the direction in which they send the ball. The results obtained showed that, depending on the category, the side of the court and the type of serve, different sequences are presented. U-14 players tend to have more defined sequences, especially with the first serve, where they hit the third shot inside the court. While the U-12s with the second serve win very few points, they hit more behind the baseline and more backhands than forehands with the third shot.

The first serves are mostly directed to the T or wide, in both categories and on both sides of the court, however, in the U-14, this pattern is much more marked. These results confirm those obtained in previous studies, which indicate that, as the level of players increases, there is a greater tendency to serve sideways. When comparing junior players with professional players, a preference for serving in the corners of the service box was observed among professional players, while younger players showed a tendency to direct serves to their opponent's body (Hizan et al., 2015).

As far as the second serves are concerned, no such defined patterns were found as with the first. In both categories, the directions are usually varied, depending on the side of the court. Previous studies also observed a marked decrease in service placement near lines (Kovalchik & Reid, 2017), as opposed to professionals. This preference for directing serves towards the body is possibly due to physical limitations associated with their development, specifically, the standard dimensions of the tennis court can make it difficult for younger players to consistently place their serves in the corners of the service box (Hizan et al., 2015). This favors the use of serves aimed at the body as a more effective strategy for these players.

In the case of U-14 players, after the first serves, they tend to mostly execute the third shot with deep forehands aimed at the opponent's backhand side, regardless of which side of the court they are on. This strategy is crucial, as the depth of the shot keeps the opponent out of offensive zones of the court (Martínez-Gallego et al., 2013). In contrast, with the second serve, the sequence of strokes is not as defined, as they can choose to hit with both the backhand and forehand. On the deuce side, the third stroke is executed from outside the court (left, center, right), and depth is sought on the opponent's side (forehand, center, or backhand). Whereas, on the advantage side, the impact is given outside and on the left side of the court, orienting the ball with depth to the center of the opponent's side.

After serving first serves, U-12 players tend to mostly hit the third shot with forehands, aiming for the center and sides of the court when they are on the deuce side, and from center and left areas on and off the court when serving from the advantage side. These shots are directed towards deep areas of the opponent's side, specifically to the backhand area when they play on the deuce side and to the forehand zone when they are on the advantage side. As for the third shot after the second serve, there is a preference for hitting more with forehands from the deuce side and with backhands from the advantage side. These shots are aimed sideways and out of the court, with the aim of sending deep balls into the opponent's court. In addition, it is common to see that many points are concluded after a mistake in the return by the opponent.

Regarding the third shot (serve +1), most of the points are hit in the central areas of the court, this may be due to the fact that the returners sought to put the ball in play, although in our study the return was not evaluated, it has been shown through descriptive analysis that a high percentage of returns are directed to the center of the court regardless of the age group, the location of the serve and the side of the court (Hizan et al., 2014).

In junior tennis, fewer direct service points are earned when compared to professionals (Kovalchik & Reid, 2017). Both U-14 and U-12 players win close to 60% of first-serve points, similar percentages have been found in previous studies for U-12 and U-16 junior players (Hizan et al., 2011). While for the second serve there are lower percentages, especially in the U-12 category, where they win only 34% of the points played with this serve. This percentage increases to 56% for U-14 players. The data of U-12 players are similar to those found by Hizan et al. (2011), where the percentage was 34% of points won with this service. These data show that, in elite junior players, the second serve is an ineffective tool and that it should be emphasized in training to improve this variable or be used when returning.

Another important aspect to consider is the number of strokes that were played per point, where most were short, in the range of 1 to 4 strokes. The importance of short-point focused training is evidenced by the fact that most points in junior tennis end with less than 4 strokes, usually due to a mistake rather than a winning shot (Klaus et al., 2017). Therefore, it is essential to work on service +1 and return +1 situations. In addition, previous studies showed that when the serve was trained with the possibility of playing a third shot, players demonstrated greater accuracy in their serve compared to an isolated approach (Krause et al., 2019).

Whereas all points in tennis start with a serve and return, and that these two strokes have been identified as the most critical in the sport (Gillet et al., 2009; O'Donoghue & Ingram, 2001; Reid et al., 2010), it stands to reason that they should receive priority attention in the training content of players. However, these strokes are worked in isolation and with low percentages of time (Krause et al., 2019). The data provided by this study can be useful for coaches to include more specific training content in the preparation of U-12 and U-14 players, focused on the work of the service situation through proposals with a high application to the real competitive game.

This study presents a novel approach with high practical implications, however, it is not without some limitations. The main one is the sample size which, although we think is adequate for the analysis carried out, the generalizability of these findings to a wider population could be limited. To address this limitation in future research, it is recommended to carry out a more thorough analysis that includes a larger sample of parties, as well as women's parties, which will allow for more robust and generalizable conclusions, as well as knowing the differences between the sexes.

CONCLUSIONS

Shot sequence analysis in junior tennis is fundamental for the development and improvement of players at this formative stage. This technique could identify patterns of play, strengths and weaknesses in strokes technique, as well as tactical effectiveness in different game situations. These findings can help us understand how strokes are executed and combined. With this, coaches can design age-appropriate training programs, addressing specific areas of improvement and maximizing the potential of each player.

PRACTICAL APPLICATIONS

It is possible to develop specific training for the serve that goes beyond the mere isolated exercise, integrating situations that allow the server to execute a third shot, preferably from the forehand. It is particularly important to focus on second serve with players under the age of 12. At this age, since the stroke is not yet fully developed, serves tend to be directed towards the opponent's body and executed at a slower speed, which often benefits the returner by allowing him to take the initiative. Therefore, it is essential to train specific patterns for the second serve, emphasizing the execution of forehands, a predominant technique among players. In addition, it is essential to practice serving in contexts that simulate real match conditions, which helps players exercise under pressure and develop tactical and strategic skills applicable in authentic game situations.

CONFLICTS OF INTEREST AND FUNDING

The authors declare that they have no conflict of interest, nor have they received any funding related to the development of this study.

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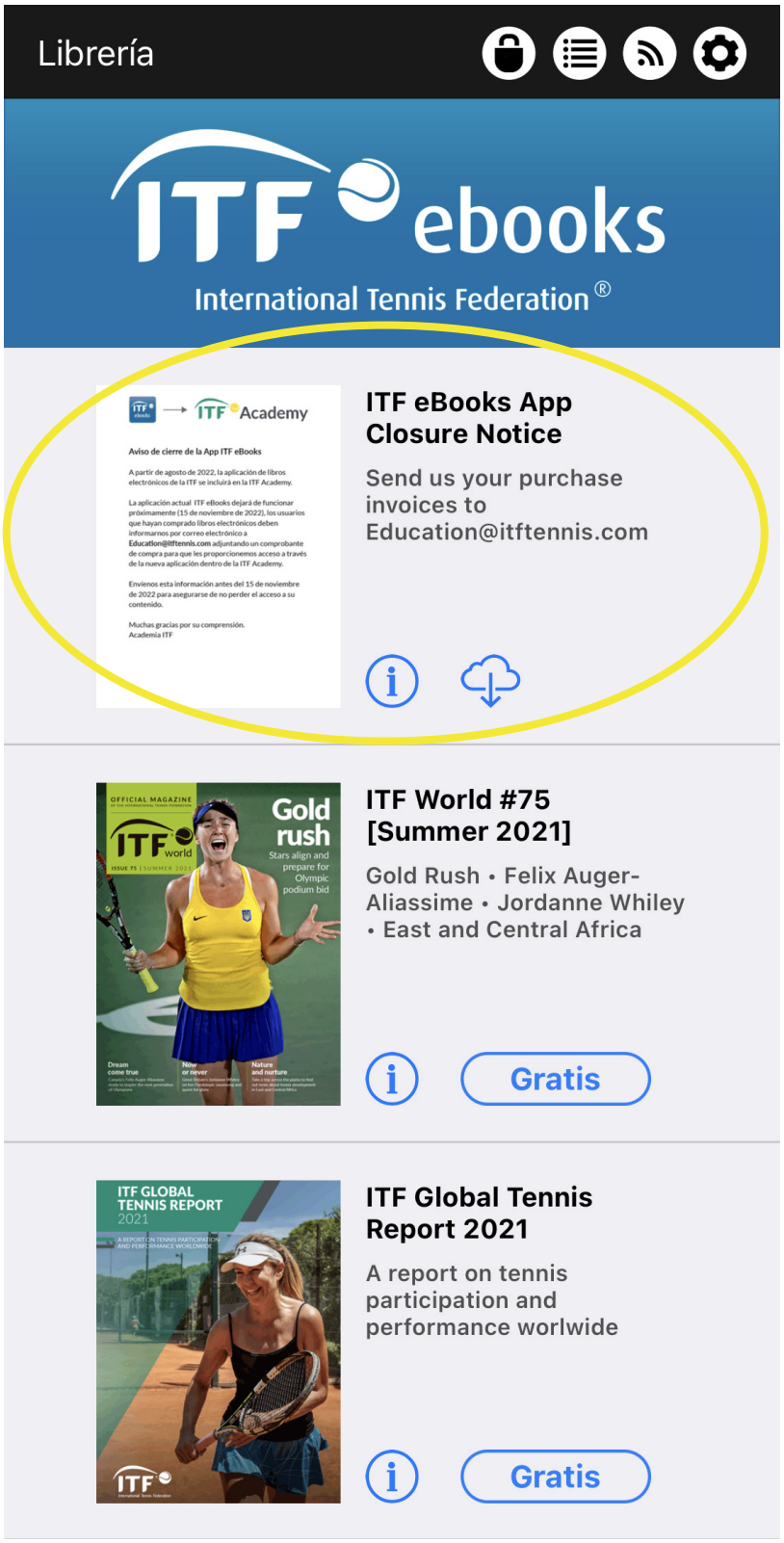

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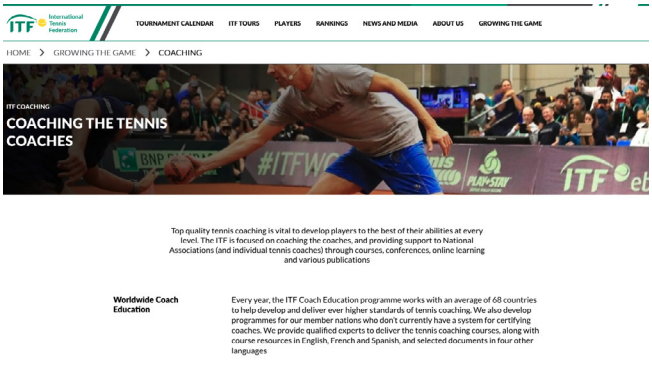

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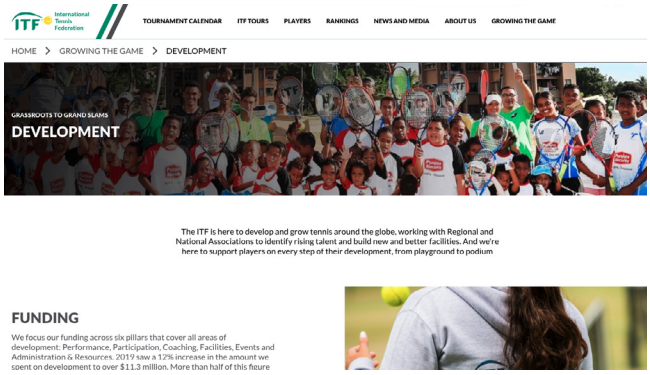

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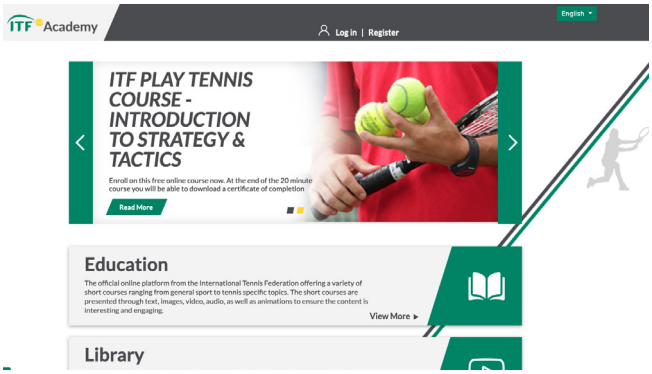

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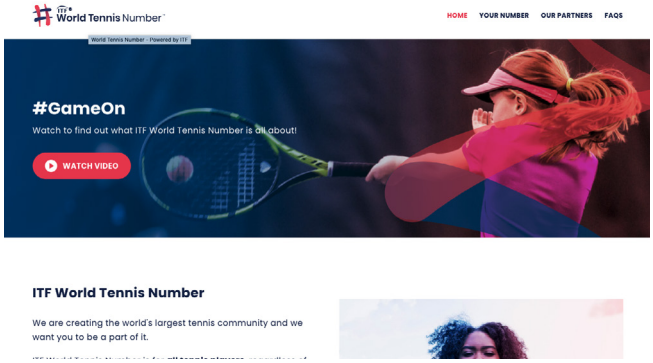

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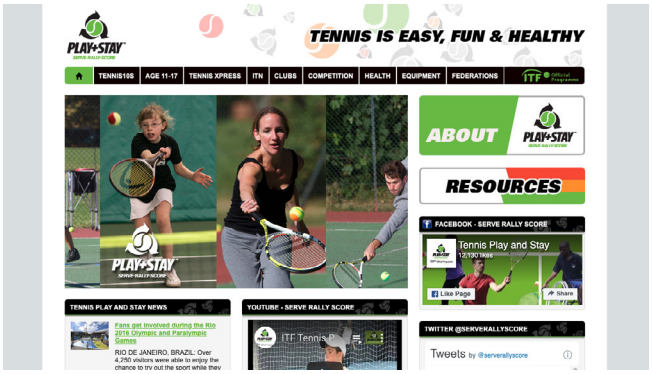

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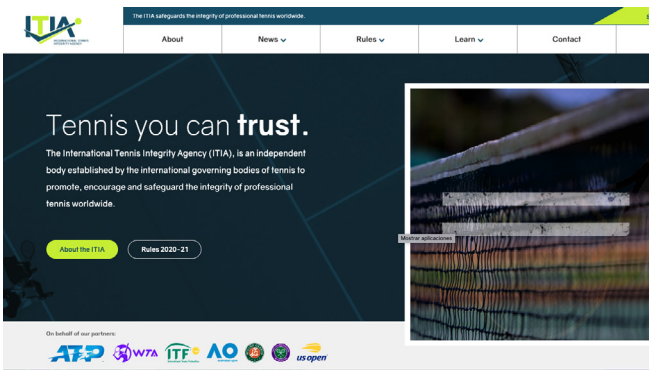

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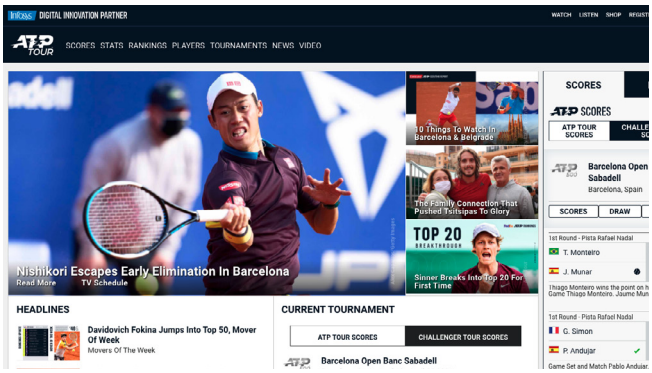

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