ITF International Tennis Federation

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Editorial

Luca Santilli & Miguel Crespo

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Welcome to issue 89 of the ITF Coaching and Sport Science Review. This issue is the first one of 2023. It is available in the ITF Academy as well as in the new page of the journal, which can be accessed here. This issue covers an interesting variety of topics which include a methodological proposal based on learning – moving and competing and a review on theories of skill acquisition, an article on blind tennis, one study on the maturity status of young players and another on the effects of HII training in tennis, a reflection on coach leadership, a contribution that explores the role of storytelling in tennis, and a summary of PAT technology applied to the game, among others.

While ITF2024 sets out the eight strategic priorities for the ITF (Figure 1), the ITF development strategy outlines the specific priorities for growing the game. The current ITF development strategy 2021-24 is a continuation of the previous four-year strategy which describes our vision and mission to increase participation and develop talented players. The strategy continues to provide a clear sense of direction and purpose for development while supporting ITF2024.

Figure 1. *ITF2024 eight strategic priorities.*

The six strategic pillars set out how the development strategy is being rolled out (Figure 2). They also cover the key areas for growing the game, providing the much-needed structure for National Associations to set their national development goals/objectives. A notable change to the strategic areas was made in 2021 when the coaching pillar was renamed education to better reflect the scope and mission of providing more educational tools and opportunities via the Academy which is the ITF's bespoke digital education platform for all stakeholders across all areas of the ITF.

Figure 2. *Six strategic pillars of the ITF development strategy.*

The nine strategic principles guide the day-to-day work of the development team and stakeholders involved in delivering the strategy (Figure 3). It became evident during the pandemic how important these principles were and still are in directing/supporting development activities globally. Thanks to the effectiveness of these principles and in particular "Technology", "Engagement", "Innovation" we were able to take the right decisions since early 2017 and were ready with digital options when the pandemic hit unexpectedly.

Figure 3. *Nine strategic principles of the ITF development strategy.*

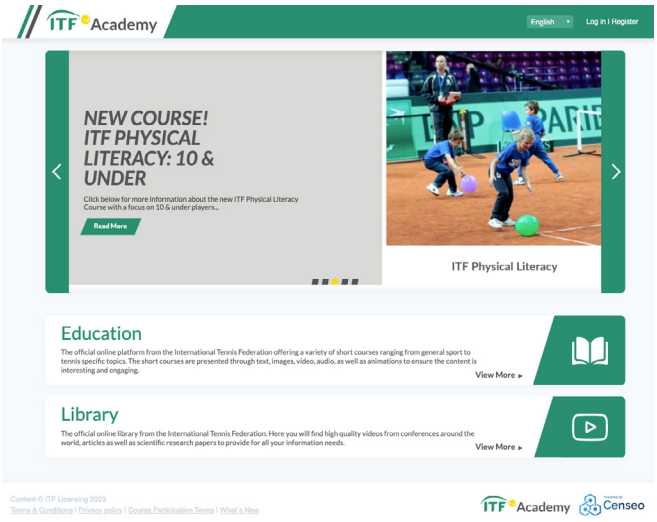
Like many other companies, the pandemic has accelerated our digital journey. The ITF Academy is a prime example of that. The ITF Academy and the World Tennis Number are two of our department's most important digital projects, but there are new digital tools to make it easier for National Associations to submit data, but also to manage their own information. COVID-19 was a challenge for everyone and in this demanding environment, the provision of services to the stakeholders was crucial.

Within the strategy area of Education, the ITF Academy was instrumental in ensuring the delivery of education activities didn't stop. We used the ITF Academy to raise the quality of delivery of tennis through the provision of information, education, certification, and professional development to ensure minimum standards are adhered to by the many thousands of deliverers involved and that their skill development is at the heart of what is provided to current and prospective players. The strategy of the ITF Academy, the educational platform of the ITF, its vision and mission fully align with those of the ITF Development Department and the whole company. The principles are a declaration of intent that emphasises the ITF's ambition of being efficient in the delivery of key services to its stakeholders. These services and products allow the member nations to implement a state-of-the-art education system which is sustainable, and evidence based.

In 2017 work started on one of the key projects of the ITF's digital strategy - the ITF Academy. The new library was launched in December 2018, and at the time the ITF had a digital platform (tennisicoach), but it was extremely limited in meeting the department's strategic training objectives. Following months of work - the ITF Academy was fully launched in March 2019 with 1000 library items and 2 online courses, in English only. By the end of the year and the Academy had 4722 registered coaches and 12 nations had signed up to the platform. The KPIs were ambitious but necessary given the anticipated growth of the platform. Face-to-face courses were still being organised, and the ITF remained the most active International Federation in partnership with Olympic Solidarity.

The outbreak of the pandemic demanded an adaptation of this pillar, and the ITF Academy grew rapidly. Content production increased from 11 courses in 2019 to 115 courses by the end of 2020. Courses were offered in four languages and the number of registered users (mostly coaches) grew exponentially to 31,372 coaches from 200 countries by the end of 2020. The adaptation required by COVID-19 produced a considerable growth in the ITF Academy which effectively provided coaches of all levels of expertise with information, education, certification, and continuous professional development. The pillar changed its name from coaching to education, to encapsulate the goal of serving a wider range of stakeholders.

Fast forward to today and certification courses are now being run in a blended format (combination of online and face-to-face learning) with specific emphasis being placed on certifying former players and national team captains this year. In addition to coaches courses we have also launched content for players, parents, managers, and referees and we're gradually adding Wheelchair and Beach tennis content. The constant evolution of the ITF Academy is a clear example of the technological innovation implemented by the ITF to better serve the National Associations.



In 2023 the ITF Academy is the digital tool on which the ITF's entire education strategy is based. All courses are run on a blended-learning basis and more than 100 national associations have signed agreements. To date, more than 90 nations are using the 200 eLearning courses available in 11 languages in the platform as their tool to delivery education and more than 260,000 users from more than 212 countries can benefit from it.

Furthermore, the ITF is pleased to announce that the 2023 ITF World Coaches Conference will take place in Bogota, Colombia from Tuesday 31 October to Thursday 2 November 2023. The event is being organised by the ITF in conjunction with the Colombian Tennis Federation and COSAT. The venue will be the American Club and Hotel Casa Dann in Bogota. The ITF World Coaches Conference is an international coaching conference which regularly attracts over 650 coaches and experts from over 90 different countries around the world. It is the showpiece of the ITF's Coach Education Programme. This 3-day in-person conference returns after a 4-year hiatus and will bring together leading international experts in coach education, player performance and sport science to present on the latest developments in these fields through practical on-court coaching presentations as well as lecture room presentations.

Speakers at previous events have included Grand Slam Champions, touring coaches, and world leading experts such as Alex Corretja, Miles Maclagan, Arantxa and Emilio Sanchez-Vicario, Albert Costa, Wayne Black, and Pat Cash. Keynote speakers at the virtual event in 2021 included Judy Murray (GBR), Paul Roetert (USA), Mark Kovacs (USA), Lucia Jimenez (ESP), Feliciano Lopez (ESP), Machar Reid (AUS), Philipp Born (GER), Jurg Buhler (SUI), Martina Hingis (SUI) and Ruben Neyens (BEL). Further information on the conference programme and hospitality packages will follow in the coming months. Online registration will open by the end of April 2023 and a link will be made available on the ITF website. In the meantime, please follow us on: https://www.instagram.com/itf.education; https://www.facebook.com/ITF.TennisAcademy; https://twitter.com/ITF_Education.

As you are aware, increasing participation for all is one of the two objectives within the ITF Development Strategy. This has not changed since the Strategy was first implemented in 2017. Within our strategy, the importance of being more data-driven to monitor and measure the implementation of the activities was required, thus the need to generate a

more robust understanding of the global landscape of tennis. Through a coordinated membership survey with 195 nations during 2018, the first edition of the ITF Global Tennis Report (the "GTR") was published in 2019. This report was described as a "game-changer for our sport" and never previously had we been able to present such a complete picture of the sport. The report highlighted our sport as gender equal, not just at the professional level but clearly at the recreation level too, with a 53/47 split across the 87-million people who play at least once per year.

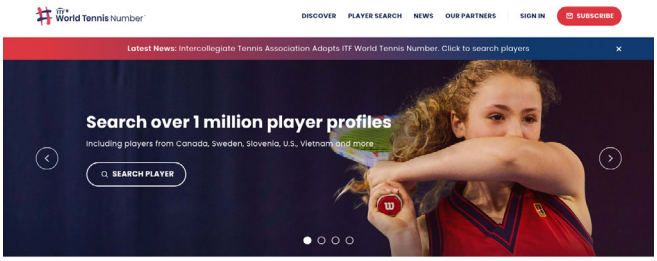
The GTR insight allowed us to establish a benchmark to set a clear strategic direction for participation – target 120-million players globally by 2030, an increase of over 30 million (known as "30by30"). This target was presented during the second ITF World Participation Conference (the "WPC"), held in London with 65 different National Associations represented creating a conversation about participation growth and sharing of best practice. Four editions of the WPC have now been organised, reaching representatives from all over the world from the ITF member nations. The next WPC will be held in 2024.

We are aware that the pandemic catalysed a somewhat greater interest and growth in tennis worldwide. Tennis was positioned as one of the safest activities to participate as research at the time suggested and as restrictions to social activities lifted globally, this offered a chance for many to return or try the sport for the first-time. This was further evidenced in our second published GTR in 2021, which indicated that there had been a 4.5% growth in total players in 2020 - a positive step towards our 30by30 target. The report also showed the resilience and the opportunities from being involved in our sport despite these difficult times and the challenges presented by Covid-19. The next GTR is planned to be published in 2024.

Our largest annual investment into the grassroots of the game is through the ITF's Junior Tennis Initiative - the "JTI". The JTI supports 142 active nations, and in 2022 5,350 deliverers provided opportunities for 250K young people to be introduced tennis for the first time within the 3,000 Primary School and tennis club environments. This focused investment in the JTI will continue through 2023 as more National Coordinators and their deliverers are provided with the opportunities to attend the 2023 ITF World Coaches Conference. The ITF have made it imperative that all National Coordinators involved in delivering their national junior programme attain a basic level of understanding through completing a set of online courses via the ITF Academy. This has enabled a minimum foundation level of delivery is operated globally in the JTI.

In the recent years as normality has returned across the world, the ITF has encouraged all active JTI nations to organise Tennis Festivals, reducing all barriers of entry for people to experience tennis for the first time and providing them follow up playing to be retained in the sport. All National Associations and their deliverers are encouraged to open tennis up to more people in existing tennis venues and/or new locations – and research tells us that the less barriers there are in place, the more new people are to experience the sport in a positive manner, for example, offering free entry, providing equipment to use on site and having someone to play during their festival, such as a coach.

We have embedded key strategic principles such as technology and innovation across the engagement within the nations. The ITF has also fully digitalised the JTI, through its online reporting platform where all nations must report on their activities delivered and so that insight can be tracked against the investment across the work through the programme. All National Coordinators are regularly updated and are provided an online forum to meet the ITF in the ten different regional areas overseen by our ITF Development Officer network. Our JTI equipment distribution is becoming more digitally orientated and customised - his is to ensure a more efficient and environmentally sustainability-focused distribution of tennis equipment globally to support the nation's junior development programmes.



The ITF World Tennis Number (WTN) project progress has been constant throughout 2022 and 2023. With many nations, regional associations and ITF sharing data and innovation for a common good for tennis. In recent months we have also seen some important milestones including Intercollegiate Tennis making WTN its exclusive rating and great progress in Asia, receiving complete match datasets for the Asian Tennis Federation and India Tennis Association Along with Singapore, Hong-Kong, Indonesia, Malaysia, Uzbekistan, Turkmenistan, Jordan, UAE, Japan, and China, This is an important opportunity for future tennis development in this region.

The ITF World Tennis Number is truly a global product. Malaysia launched in December, we integrated directly with a new local 3rd Party software provider to share data and create WTNs. The Egyptian database had names in Arabic, which ITF translated using ITF software to match to Egyptian players records in other databases. Tennis New Zealand is the first nation in Oceania to launch in and a nation with plans to use WTN in several different ways, including in tournaments, to create rankings and new leagues.

The whole project is founded on safe, secure and efficient data collection. Tournament Desk the tournament management system rolled out at very competitive costs for the ITF NAs by ClubSpark has had lots of encouraging interest. This will enable federations to both seamlessly supply results and utilise ratings in their national tournaments. The idea of a consistent data ecosystem for tennis has been extended to other software pioneers such as Tournament Software in Europe and Tennis Integrado in South America.

The global rating is now very much live with a central database and systems managed by ITF alongside NAs and RAs. 1.5 million player profiles are available on worldtennisnumber.com website. These are freely available to players. Registrations and the ability to self-submit results will be made available with selected national associations to recreational players in 2023. The Database has 22 million match records from 45 Federations including Grand Slam tournaments and down to Local Leagues. ITF WTNs have been used as acceptance criteria in Juniors and Masters Tours from April 2022. ITF is collecting data directly from multiple Technical Partners and from the new Tournament Desk system. To find out more about ITF World Tennis Number please visit www.worldtennisnumber.com

From an overall development perspective, our aim this year is to fully return to tennis across all our six strategic pillars and ensure we utilise effectively the entire 2023 budget to increase the number and standard of players across the six regions. Over the next few months, we have very ambitious objectives and KPIs to meet as well as bespoken digital products to improve and roll out along with some exciting tennis projects to drive.

We do hope that what we have shared in this article shows how the ITF is thinking creatively about how to get more people involved in our sport. Most of all we look forward to working and supporting our member nations as you embark on your digitalisation journey so that we can reach and engage with the millions of tennis players that are not yet known to us and thus create opportunities for all involved.

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 in the most recent issue page on the ITF Academy. We hope that you enjoy reading the 89th edition of the ITF Coaching and Sport Science Review.

RECOMMENDED ITF TENNIS ACADEMY CONTENT (CLICK BELOW)

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Learn, Move, Compete: An alternative approach to mini tennis lessons

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ABSTRACT

In this article, we look at how competition is presented in the typical mini tennis lesson plan used by federations, finding that it usually occurs once, at the end of the session. We then explore some of the limitations associated with competition in this framework. Following that, we discuss the importance of developing competitive capabilities, and propose an alternative way of designing the mini tennis lesson to provide more opportunity for competition while systematically developing tactical and technical skills in a manner consistent with a game based approach, and findings from skill acquisition research. This framework, we suggest, provides an upgrade to the game based approach used at the mini tennis level, and offers a more fertile environment in which to develop competitive performers alongside the tactical and technical performance factors.

Key words: Mini tennis, competition, methodology

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INTRODUCTION

Over the past two decades, modified forms of tennis have proliferated across the world. Federations have encouraged the use of low compression balls, modified court spaces and scaled down equipment to help young players serve, rally, score, and develop their skills across the four performance factors. This has coincided with an increased emphasis of delivering tennis lessons using modern approaches like the game based approach (Crespo, 1999; Pankhurst, 1999) and the constraints-led approach (Davids, et al, 2008). A wide range of nomenclature has been used to label this family of approaches such as the Action Method, Teaching Games for Understanding, GameSense, Game-Centred Approach, and many more (Unierzyski & Crespo, 2007). While these approaches have slightly different origins and theoretical underpinnings, they all agree that tennis is an open skill sport, and learning to play tennis is not just about developing strokes in isolation, but instead involves different game situations (serving, returning, both back, approaching or at the net, opponent approaching or at the net) and tactical intentions (offense, neutral, defence). Though a tennis lesson for a group of 8 year olds may not involve playing a full match in the traditional sense, the activities involved in the lesson typically resemble familiar game situations with tactical intentions, modified and adapted for the ability of the players. In short, it should look like a game of tennis. In the literature, game based methodologies encourage the playing of the game at the start of the lesson in order to observe and analyse the needs of the players, establish a tactical objective that can be achieved using technical principles. This objective is then trained before being put back into a match-like situation at the end of the lesson, forming an open-closed-open pattern across the course of the lesson (Pankhurst, 1999; ITF, 2007). Despite this methodological approach, mini tennis group lesson plans often do not include competition at the start of the lesson, and instead include it only at the end of the lesson. Table 1 illustrates some mini tennis lesson formats used by a number of federations in their curricula.

Table 1

Sample of Mini Tennis Lesson Structures.

LTA Mini Tennis (2001)	Tennis Australia Hotshots (2008)	Tennis Canada Learn to Play (2009)	USTA Net Generation (2017)	LTA Youth (2020)
Warm-up	Movement activity	Warm-up	Warm-up	Warm-up
Main theme	Throwing and catching activity	I Can Rally	Skills (athletic)	Body and Ball
Progression or Regression	Striking activity	I Can Rally	Skills (tennis)	Body and Racket
Competition	Serve, Rally, Score	I Can Play Points	Game	Game

While each federation has their own terminology for the different stage of the lesson, the structure of the lessons are similar, with competition appearing at the end. This potentially limits the development of competitive capabilities, since players are only exposed to one competitive opportunity during the session.

LIMITATIONS OF THE CURRENT APPROACH

An obvious limitation of leaving competition until the end of the session is that children are not exposed to competition very frequently. Developing a skill requires frequent exposure to a situation in which the skill is needed. If you want to develop the technical skill of hitting a slice backhand that stays low after the bounce, then it will require that the skill is practised frequently across time. Instead of practising a slice backhand for ten minutes at the end of a tennis lesson, it would be better to practise more frequently (little and often) across the lesson. Correspondingly, in order to develop better competitors, it is logical to increase the frequency of competitive opportunity that players are exposed to.

Second, because competitive opportunity appears only at the end of the session, players may be physically fatigued and mentally exhausted. While there is of course a good case to be made for training competitive skill under conditions of stress, it is not the only condition under which it can, or should, be trained. It is possible that developing competitiveness under a variety of conditions (e.g., when fresh, when energy is middling, when fatigued) more closely replicates the demands of competition in a tennis match.

Third, while it is well established that young children have short attention spans (Crespo, 2010), there is increasing evidence that the current generation of children experiencing the mini tennis lesson (i.e., those born 2010 or later) have shorter attention spans than previous generations (Twenge, 2017), and possess a comparatively lower degree of physical literacy than would be expected for their age (O'Brien et al., 2016). This increases the need to reimagine and redesign the mini tennis lesson to engage and excite the current generation of tennis playing children.

These are important considerations because tennis is a game that is inherently combative in nature. At the end of a match, one individual or team wins, and the other is vanquished. Tennis players of all ages have to be equipped to deal with this fact, as it is an inescapable part of our sport. It is therefore crucial that tennis coaches help players at every level develop not just their tactics and technique, but also their competitive capability. In order to develop competitive capability, children have to be exposed to frequent competitive opportunity during the mini tennis lesson. Possessing, for instance, appropriate tactical and technical skills is not enough. When competing against another player of a similar ability, it would be advantageous to be a great competitor and not just a good hitter of the ball.

It is therefore important to upgrade the game based approach typically used for mini tennis lessons, and integrate competition more frequently throughout the lesson.

DEVELOPING COMPETITIVE CAPABILITIES

While everyone starts with differing levels of competitiveness, it is, nonetheless, a skill, that can be developed (Dweck, 2017, p. 52). Competitiveness is not a fixed trait like shoe size or height (you cannot, for instance, train yourself to have bigger feet or become taller). Just as a player can develop the technical skill of hitting a slice serve, so too they can develop their competitive skill. For example, a player can gradually change their attitude, mindset, and beliefs to become more competitive:

- I chase the ball → I beat the bounce
- Sometimes the ball bounces twice → I never let the ball bounce twice, I always touch it
- People can out-rally me → No one out-rallies me
- I get anxious at the end of a match → I play my best tennis at the end of the match

As with any skill, these competitive beliefs, attitudes and mindsets are not developed overnight. Rather, this sort of transformation happens gradually, little by little, over a period of time. If tennis coaches want to help players become better competitors, it is important that this is reflected in the format and nature of the tennis lesson. If this is not reflected, then the corresponding competitive skills are less likely to emerge, in the same way that a player is unlikely to improve their serve if they do not spend much time practising it, or only practise serving in the last ten minutes of their lesson.

Specifically then, the tennis lesson should provide frequent opportunities for those competitive attitudes and identities to emerge while simultaneously developing tactical and technical skills required to play the game. It can be argued that the typical mini tennis lesson format – as it is presented in the coach education resources and training curricula of many federations – underplays this aspect of the sport, and relegates competition to the end of the session. With this approach, most of the lesson is learning or drilling, and only a small portion of the lesson is competition. In contrast, short, simple, and frequent competition helps normalise the competitive nature of tennis, which is important, because competition is one of the key drivers of the sport (Tennant, 2010). Frequent competition also has the additional benefit of showing the coach how well motor skill has been retained and transferred from practice to competition.

It is therefore necessary to consider an alternative structure for the mini tennis lesson that emphasises competition. Below is a systematic framework that helps children experience frequent competitive opportunity while simultaneously developing the tactical and technical skills needed to serve, rally, and score with each other. We suggest that this format can be much more dynamic and engaging than the typical mini tennis lesson format, more closely meets the attentional needs of the current generation of children learning to play tennis, and increases the likelihood of developing healthy competitors.

LEARN, MOVE, COMPETE

In order to provide more opportunities for competition within the mini tennis lesson, we propose an alternative structure, using a game based approach, that includes more frequent competitive opportunity for players. By reimagining the mini tennis lesson in this way, tennis players learn, move, and compete throughout the lesson. They are therefore exposed to competition much more frequently than they would be using the typical approach. This format is not a replacement

for a game based approach, but rather an upgrade to it, via the systematic inclusion of more competition. Figure 1 exemplifies the difference between the lesson formats, and shows the increased presence of competitive opportunity in the learn, move, compete format. The typical mini tennis lesson features only a small element of competition. The learn, move, compete format evenly distributes the lesson between learning, drilling (movement) and competition. In both variations of the learn, move, compete format, one third of the lesson is spent competing, and that competition is spaced out across the session.

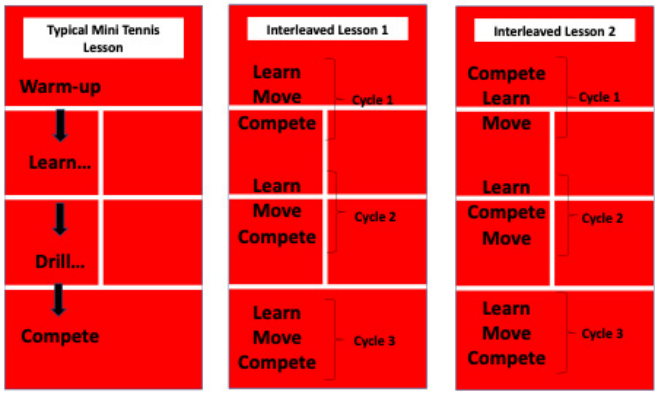

Figure 1. *A comparison of different lesson formats*

Coaches are encouraged to mix up the order of activity to best suit the needs of the players. The important point is that competitive opportunity is not left until the end of the lesson, but occurs frequently throughout. This gives players the opportunity to integrate learning and develop competitive capability, and coaches can observe the impact of their interventions.

The learn, move, compete format uses interleaved practise design to integrate more competition. Interleaving involves switching between different practise situations and varying the order of practise (Weinstein et al., 2018, p. 93). The typical mini tennis lesson progresses in a linear manner until finally, at the end of the lesson, the skill is ready to be integrated into competition. While the linearity of this approach seems intuitive, it can also become stale and lack dynamism over time. The learn, move, compete format, on the other hand, is non-linear, and switches between three situations more frequently. Research has shown that this is an effective practise design. Players are less prone to mental fatigue by drilling one single skill over and over again, because the situation is varied frequently. Players must retrieve different solutions to the problems and situations they are faced with (Lee & Schmidt, 2014). In this regard, they are less likely to be on auto-pilot. This is particularly useful because it reflects the reality of playing tennis, where you do not face the same situation over and over again without change, but instead must be able to discriminate between different situations within the game. For this reason, interleaving also improves decision-making and problem-solving skills. When a player selects a motor skill that is incorrect, or does not meet the demands of the situation, this strengthens understanding and helps players decide which strategy or movement solution should be used in that situation (Weinstein et al., 2018, p. 96). Research shows that interleaving practise is an effective learning strategy, and leads to higher retention and transfer of motor skill (Taylor & Rohrer, 2010; Lee & Schmidt 2014). Compared with the linear lesson format that many federations are currently using, the non-linear design of learn, move, compete, combined with more frequent competition, has the potential to help players become more skilful and more competitive.

Learn

In tandem with this format, we present a systematic framework to develop rally skills across a range of abilities, from floor tennis, to children rallying with each other using rackets. This provides coaches with a roadmap for their lesson planning based on the current ability of the players they are working with. Using this pathway in tandem with the learn, move, compete structure still provides players with the opportunity to develop their tactical and technical skills, while simultaneously developing their competitive capabilities. Figure 2 illustrates the pathway for developing rally skills. Within each stage of the pathway, it is recommended that the skill is developed by moving progressively from easy to more challenging. This is done simply by first learning the skill with minimal movement or variation. Then, performing the skill with additional movement or an added level of variation or coordination. Table 2 shows partial lesson plan for players at the blue stage, using this learn, move, compete format.

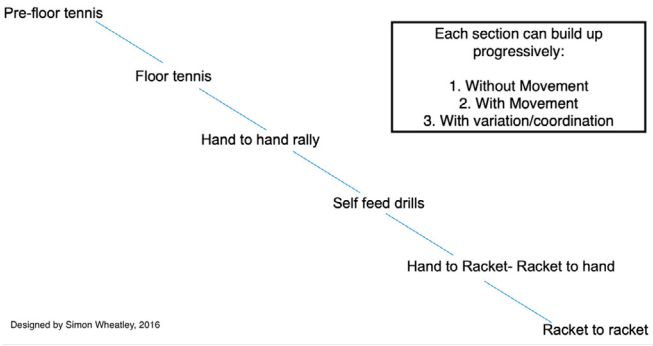

Figure 2. *A progressive pathway for developing rally skills.*

Table 2

Learn, move, compete partial lesson plan

Aim: Develop rally accuracy by controlling direction of the ball **Activity**: Floor tennis rally through a goal positioned between two players	
Learn	Stop the ball with racket, then point the strings at the ball and towards the goal. Use a push feeling back keeping the strings connected to the ball for long as possible through the hitting zone.
Move	Movement/variation options: - Send the ball, then run and touch a sideline after each shot - Stop the ball, run a circle around the ball, then send - Stop the ball, jump back and forth over the ball, then send - No stopping the ball, push straight back
Compete	Players race to see which pair can have a floor tennis rally of 10 shots (with or without a movement variation).

Players could then go through another cycle of these three stages - learn, move, compete – with another skill relevant to rally accuracy. This could involve the same floor tennis activity, and this time players direct the ball through two different goals placed side by side. Or perhaps the floor tennis rally now takes place off both the forehand and backhand side. These are just two of myriad options to develop the skill of rally accuracy, and coaches are limited only by their imagination (and the imagination of the players!) when it comes to what and how to add elements of variation and coordination, all of which help increase the level of challenge and develop skilfulness.

Move

By adding different elements of movement or coordination into each activity, a learning effect called contextual interference occurs. This is when practise conditions or characteristics are varied for the learner. Research has shown that contextual interference leads to higher retention and higher transfer of motor skill (Magill & Hall, 1990). It is therefore possible that the learn, move, compete approach may help players become more skilful more quickly than the typical framework for mini tennis lessons that federations are using in their coach education.

Compete

While the benefits of more frequent competition have been outlined, it is helpful to provide a framework for categorising competition as well as some practical examples of that can be used quickly and frequently during the mini tennis lesson. Schematically, competition can be broken down into four categories: individual, cooperative, cooperatively competitive, and competitive, as seen in Table 3. These competitive categories can be progressively layered into the lesson structure.

Individual competition is the idea of improving your best score. Cooperative competition is the idea of working with a partner or as a group to get the best score. Individual and cooperative competition could be used as competitive elements in the first learn, move, compete cycle in order to expose players to the concept of competition, and provide a rationale for subsequent learning and skill development.

Cooperatively competitive competition is the idea of working with a partner or as part of a team, competing against other teams to get the best score. This could be used as a competitive element in the second or third learn, move, compete cycle. Here the competitive element has progressed and players are exposed to the possibility of beating another team.

Finally, (and perhaps the most relatable form of competition for tennis coaches and players) is the competitive situation where two players are competing against each other. This could be used as the competitive element in the third learn, move, compete cycle. With two players competing against each other, this is the form of competition that is most representative of the competitive demands of a tennis match.

Table 3

Four competitive categories.

Competition Category	Examples
1. Individual (Learn, move, compete cycle 1)	- How many tap ups can you achieve in one minute? - How many self-feeds can you hit to the target area? - How many times in a row can you serve without hitting the net?
2. Cooperative (Learn, move, compete cycle 1 or 2)	- How many tap ups can we get together as a group? - What's your highest throw and catch rally with a partner? - How many times can you complete the sequence: serve, return, 3rd shot?
3. Cooperatively Competitive (Learn, move, compete cycle 2 or 3)	- Which pair can be first to have a throw and catch rally of ten shots? - Which team can get the highest groundstroke to volley rally? - Which team can get the highest number of groundstrokes in a minute?
4. Competitive (Learn, move, compete cycle 3)	- 1 v 1, who can rally the ball into the target area most often? - 1 v 1, can you out-rally your opponent? - 1 v 1, can you win three points in a row against your opponent?

The order and use of these competitive categories will of course depend upon the dynamic of the players within the group and the aim and intention of the lesson. The following progressive approach to layering competition is a logical recommendation, but depending on the ability and needs of the players, coaches could just as easily interleave match play or conditioned points at each stage of the learn, move, compete cycle. The important point is that there is some element of competition occurring frequently across the lesson, in order to best develop the competitive capabilities of the players.

By using these competition categories as part of the learn, move, compete format, coaches can increase the frequency of competitive opportunity available within the mini tennis lesson. This is an important component, especially at the recreational level of the sport, where players may not have been exposed to formal tennis competition before embarking on mini tennis lessons. Tennis specific research has demonstrated that young players newly exposed to the sport are less competitive than children with a previous sporting background (Rasmus & Kocur, 2006). Given this fact, it is logical to integrate competitive opportunities throughout the mini tennis lesson so that young children have the opportunity to develop their competitive capabilities. This also normalises the idea that tennis is a competitive game, and not just an activity. This may have the additional benefit that more people are more likely to play tennis matches more often, which is good news for coaches and tennis operators because it is likely to improve player retention.

CONCLUSION

As we have outlined, the format of the archetypal mini tennis lesson has not changed much in twenty years. While it has served its purpose for federations, there are some limitations with the current format, particularly in the way it de facto relegates the importance of competition. Competitive capability is an important performance factor for tennis players of any age and stage of development, and so federations and coaches should look for ways to enhance the competitive experience within the mini tennis lesson. By reimagining the structure of the mini tennis lesson, the learn, move, compete framework offers a solution to this problem. It provides a simple framework for coaches to develop tactical and technical skills in conjunction with competitive skills in equal measure. Reimagining the format of the mini tennis lesson in this manner should be seen not as a replacement for, but an upgrade to, the game based approach. It has the potential to change the way children experience the sport, and enhances and normalises the competitive experience. Designing mini tennis lessons using the learn, move, compete structure offers a dynamic and exciting learning environment for tennis players to become more skilful across all the performance factors. We encourage coaches to test this out and apply the idea in their club environments.

CONFLICT OF INTEREST AND FUNDING

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Experiments to identify the optimal sound to use in a new sound ball to improve recruitment, retention, health, and wellness for blind and visually impaired tennis players

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ABSTRACT

Within the sport of Blind and Visually Impaired (BVI) Tennis, the choice of sound is important in locating the ball. We conducted two experiments to choose a sound that will improve the localizability of the ball, in response to a request for new ball development from the International Blind Tennis Association (IBTA). We screened sounds (freesounds.com) for characteristics that the brain best exploits for sound source localization (Risoud et al, 2018). Sample sounds (23) were tested on an outdoor BVI court in a public park using five Bluetooth speakers, and then replicated in an indoor setting; the environments were otherwise naturalistic and unaltered. Blindfolded-sighted participants (n=29) pointed to where they believed sounds originated, by moving an arrow attached to a large protractor. Degree angles were recorded and converted to absolute degree angle error. The standard BVI tennis rattle ball sound resulted in 9.56 degrees of average angular error at a 30-foot distance. After eliminating sounds that 2 or more people either could not hear in either soundscape or that people had degree angle errors over 15 degrees, we discovered a superior localizable sound that resulted in only 4.00 degrees of average angular error at a 30-foot distance.

Key words: Blind tennis, sound ball, sound source localization, visually impaired athletes

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INTRODUCTION

Blind and Visually Impaired (BVI) Tennis is a growing sport worldwide. Since Mr. Takei Miyoshi invented Blind Tennis in Japan in 1984 (InternationalBlindTennis.org), the sport has grown to be played in at least 30 countries (IBTA) at the tournament level in Ireland, England, Scotland, Poland, Japan, etc., and at the club level in others. The growth potential is large, including expanding the sport to entire countries. In the US the Highland Park Tennis Club (blindtennis.org) is working at the grassroots level in partnership with the United States Tennis Association (USTA) to 'plant' new clinics for BVI players nationally and to improve the ease of learning the sport. Given the existing barriers to exercise faced by people with BVI (Richardson et al, 2022), there is a clear need for research to help enable increased participation.

BVI Tennis has a modified format that adapts the sport to players with different visual acuities, rated as B1-B4 with B1 players being profoundly blind and B2-B3 players having varying degrees of vision (low to high). B2-B4 players use a smaller court than fully sighted players use, with highly visible tape lines and a center-of-net height of 90 cm. Players of all sight classifications must land the first bounce in their opponent's court. B1 and B2 players must strike the ball prior to the fourth bounce, B3 before the third bounce, and B4 before the second bounce. B1 players play on an even smaller

Maggi Ostrowski, Board member of the United States Blind Tennis Association and two-time paralympic B1 athlete, hits a serve from behind a tactile baseline at the 2023 International Blind and Visually Impaired Tennis Education Conference and Tournament at the USTA National Campus in Orlando, Florida. Photo credit: Jennifer Roth / USBTA.

court with tactile lines, with a lower net (center-of-net height: 83 cm) than tennis for players with full vision. All BVI players use a sound ball, and a smaller racquet (B1 players' racquets are up to 23 inches in length; B2-B3 up to 25 inches; B4 up to 27 inches). Court sizes are frequently reviewed, and sometimes change to accommodate the performance of the different balls that have been adopted by the sport (IBTA Technical Manual, 2019).

One challenging aspect of Tennis for no-vision and low-vision athletes that we hope to facilitate with our research, is the need to track a moving ball by sound, determining its trajectory and velocity in a 3-dimensional space. The current standard BVI audible ball contains a 'mechanical' rattle constructed from a hollow plastic dimpled ball containing ball bearings, inserted into a foam outer ball (9 cm circumference, 28-32 grams). This ball only generates a brief, rattle sound whenever the ball changes momentum (hit or bounce) but remains silent at steady velocities or constant spin, making localization and tracking the ball a difficult task to learn. Athletes are challenged to find this mostly-silent ball in the x-, y-, and z-planes while accounting for forward velocity and diminished height with each bounce. With these challenges, a volley is nearly impossible.

Second, the rattle sound is not the optimal sound for source localization. Sound source localization is a challenge in the x-, y-, and z- dimensions for a moving object. The cognitive neuroscience of sound source localization informs us that the brain exploits different sound qualities to localize sounds in each of the x-, y-, and z-planes (Grothe, Pecka, & McAlpine, 2010). The horizontal plane provides both interaural time differences and level differences (Møller, Sørensen, Hammershøi, & Jensen, 1995). The vertical plane does not have binaural cues, as human ears are relatively level on the sides of our heads, and therefore relies on spectral cues (Wallis & Lee, 2015) characterized by the head-related or anatomical transfer function specific to an individual. Depth is largely conveyed by intensity (Finnegan, Proulx, & O'Neill, 2016), though reverberation contributes, too. Moreover, sound 'color' such as the varieties of frequencies that convey the meaning or relevance of a sound (Derey, Rauschecker, Formisano, Valente, & de Gelder, 2017), and the bandwidth of frequencies (Yost & Zhong, 2014) are important in a number of dimensions. For each of those sound qualities in those planes, there are optimal sound characteristics of amplitude and frequency of the sound wavelengths to achieve sound source localization (for a review of the physics of sound source localization, see Risoud et al, 2018). Furthermore, ambient sounds such as traffic noise, conversation, dogs barking, and birdsong, heard often on an outdoor tennis court, attenuate the frequencies produced by the sound ball (Docherty, 1972).

Using the current IBTA standard rattle ball, new players work for years to achieve a rally, and international tournament-level players achieve only a short rally. Given that the ball only makes a noise when struck with the racquet and in a brief moment during and after a bounce, new B1 players at our clinic as well as sighted blindfolded players swat at the air where they believe the ball to be. An experienced B1 player from Germany and current IBTA Board member shared:

"I have yet to see a B1 player who manages to consciously hit volleys. The balls currently available are either bouncing too low, moving too fast, or they are not making enough noise to track them easily during all stages of their journey across the net. The ability to track a blind tennis ball is key to delivering quality shots and to being at the right place at the right time. Finding a good sound is difficult, as sound changes as it travels at high speed. There are also noises around the player, and in this sound carpet the tennis ball has to stick out, no matter whether in a one on one or in a noisy tournament environment" (Kaplan, Chris, Personal communication 8/31/2021).

The International Blind Tennis Association (IBTA) requested new ball development (Martin Etheridge, IBTA, personal communication, 2019). The Highland Park Tennis Club's Blind and Visually Impaired (BVI) Tennis program (blindtennis.org), located at public courts in Pittsburgh, in partnership with the USTA, has the potential to expand the health and wellness opportunities that tennis can provide to the over 2 million blind and 7 million visually impaired people living in the US (cdc.gov). We have the potential to revolutionize the sport, increasing the potential for longer rally, possibly introducing volleys altogether, and reaching more athletes by reducing the time to become proficient at 'finding' the ball from years to days. This combination has the potential to increase enjoyment, health, and wellness by maintaining players through the difficult learning phase. Given the correlation between enjoyment and commitment to the sport (Casper et al., 2007), we believe we can improve the potential health benefits of tennis in BVI player by extending their rally (Groppel & DiNubile, 2009; Kovacs et al., 2016; Oja et al., 2017; Pluim et al., 2007), as well as increase cognitive benefits including improved spatial cognition in blind athletes across multiple blind sports that translates to the player's life (Shiota and Tokui, 2017; Velten et al, 2014).

We conducted the experiments described here to optimize the development of a new electronic sound ball that is easier to localize than the standard BVI 'rattle ball.' This optimized ball could allow players to achieve greater proficiency faster, increasing the enjoyment of the sport, increasing the length of points that could improve recruitment, retention, health, and wellness benefits, promoting the love of tennis to new and existing players.

METHODS AND PROCEDURES

We interviewed blind tennis players, board members of the IBTA, and new B1 adult athletes at our BVI Tennis clinic to determine the needs for new ball development, compiled input on the performance of the current ball, generated a 'wish list' of ball features for a new ball (durable, low cost, sound that is easy to localize, bounces well), as well as created a list of a variety of sounds they find to be easily localizable for later assessment.

Sound selection

We screened sounds (freesounds.org) for the characteristics that the brain best exploits for sound source localization (Risoud et al, 2018) via Fourier transformations of the sound wavelengths using a cell phone application (FFT Spectrum Analyzer, version 17). To compare performance to the standard BVI Tennis rattle sound, we recorded the rattle, then normalized this and all sounds to the same peak amplitude. All sounds repeated continuously. We selected 23 sample sounds with different characteristics for our sound localization experiments.

Participants

Participants completed and signed an informed consent form, and 22 sighted participants (ages 18-80 years, mean age 51.0 years; 10 F, 12 M) completed a version of the experiment on an outdoor court; 7 completed the indoor experiment (ages 18-70 years, mean age 35.7 years; 3F, 4M). This research protocol was approved by Carlow University's Institutional Research Review Board.

Procedures

Twenty-three sample sounds were tested on an outdoor BVI court in a public park using five Bluetooth speakers placed 9.144 meters (30 feet, the approximate baseline to baseline distance on a B1 BVI Tennis court) from the participants at 10-degree increments ranging from 70 to 110 degrees. A convenience sample of blindfolded sighted participants, recruited from the tennis and university communities, were given 3 seconds to point to where they believed sounds originated, using an arrow attached to a large protractor. Degree angles were recorded from the protractor and converted to absolute degree angular error relative to the actual location of the speaker generating the sound. Each participant located 90 sounds selected randomly and played from a randomly selected speaker by a Python script run in an Anaconda environment. The experiment was replicated in an indoor setting, both in unaltered, naturalistic soundscapes. For a video demonstration, visit https://www.youtube.com/watch?v=2UKlGfMdYLA.

Figure 1. *Members of the research team (from left to right Dr. Kaihong Liu, Dr. Jennifer Roth, Christen Rose, and Isabella Liu-Lopez) standing behind the protractor participants used to indicate their best guess as to the location of each sound sampled.*

Data analysis

Before subjecting the data to a t-test to compare the performance on the standard rattle sound to the best-performing sound, we eliminated sounds that 2 or more participants could not hear in either of the soundscapes, and that had average degree angle errors over 15 degrees. We have patent pending status for the process of developing this sound device.

We conducted a brief pilot study on an outdoor tennis court comparing player performance using a foam ball containing the prototype circuit playing the best sound to player performance using the standard BVI Tennis ball. We hit each ball to 2 blindfolded players and asked them to make contact with the ball using their own tennis racquet.

RESULTS

Participants were able to localize 12 of the 23 new sounds better than the standard rattle sound used in BVI Tennis. Participants' performance at localizing the best-performing sound (M = 4.0 degrees of error, SE = 0.92) was significantly better than their performance at localizing the rattle sound (M = 9.56 degrees of error, SE = 1.76) even after making the standard rattle sound continuous ($t(21) = 20.76$, $p < .0001$).

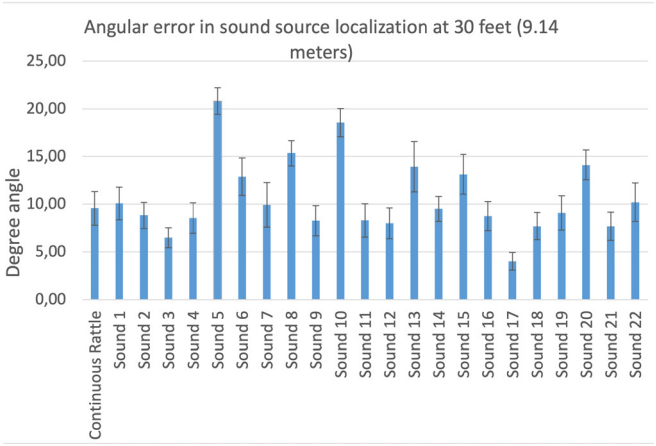

Figure 2. *Average performance across participants in locating the source of 23 sounds. Performance is plotted as average degree angle error from the location of the sound source (average absolute difference between where participants pointed with the arrow on the protractor and where the sound source was located). The Continuous Rattle sound is a recording of the standard sound ball adopted by the International Blind Tennis Association at the time the experiment was conducted.*

In the pilot study on an outdoor tennis court, blindfolded players successfully made contact with the foam ball containing the prototype circuit playing the best sound 100% of the time. They made contact with the standard BVI Tennis ball 50% of the time.

DISCUSSION

The results of the current experiments demonstrate that it is possible to develop an electronic sound ball for BVI tennis players that will lead to greater success in the sport. We identified a sound that blindfolded participants were able to localize with 4.0 degrees of angular error compared to the sound of the standard, BVI Tennis ball at 9.56 degrees of angular error, though both sounds were played continuously. One challenge in BVI Tennis is that the sound of the standard BVI Tennis ball occurs only briefly after a momentum change. This new, better-performing sound was then recorded onto an electronic circuit so that it can play continuously. This circuit was implanted in a foam ball similar to the foam ball used in BVI Tennis. In a brief pilot study, blindfolded tennis players were better able to locate this sound versus the current sound used in BVI tennis in a realistic tennis scenario. Initial testing of the current prototype ball, by hitting the ball at a participant across the net, revealed that players are roughly twice as likely to track the electronic sound ball successfully in a realistic tennis setting compared to the standard ball used currently in Blind/VI tennis. In these preliminary tests, our prototype sound-producing circuit, inserted in a standard foam BVI Tennis ball, is robust to the forces of tennis and bounces similarly to the standard BVI ball. Furthermore, the

continuous sound allows B1 players to retrieve their own ball without assistance, adapting the equipment of tennis to the needs of the athletes, rather than asking the athletes to adapt to the equipment.

We believe our selection of a new sound to be used in an electronic sound ball for BVI tennis will help to accomplish the USTA's goals of expanding tennis while increasing the health and wellness of new and existing players (Allen, Townsend, & Davies, 2021) through the development of equipment that meets the needs of the players in a way that increases the enjoyment of the sport. This might even provide an interesting inclusive design for training even sighted tennis players, as multisensory cues tend to enhance performance and might make it enjoyable for people playing for the first time (Lloyd-Esenkaya, Lloyd-Esenkaya, O'Neill, & Proulx, 2020), and like other accessible games could allow sighted and visually impaired players to play together (Gonçalves et al, 2021).

This ongoing project has the potential to result in greater recruitment and retention of players to BVI Tennis. This has the potential to expand the health and wellness opportunities that tennis can provide to the over 2 million blind and 7 million visually impaired people living in the US (cdc.gov), and equivalent groups in other countries. This project has the potential to result in longer rally, possibly introducing volleys altogether, and reach more athletes by reducing time and frustration to become proficient at 'finding' the ball. These potential improvements to the sport could increase enjoyment, health, and wellness, given the correlation between enjoyment and commitment to a sport (Casper et al., 2007). The potential health benefits of tennis in BVI players could improve if we do extend their rally (Groppel & DiNubile, 2009; Kovacs et al., 2016; Oja et al., 2017; Pluim et al., 2007). An increase in duration of points, and increased commitment to the sport, could lead to improved spatial cognition (Pasqualotto & Proulx, 2012) that will likely translate to the player's life outside of sport (Shiota & Tokui, 2017; Velten et al, 2014).

CONCLUSION

In conclusion, we identified a new electronic sound to be used in an electronic sound ball for BVI Tennis that is able to be localized more successfully than the rattle noise used currently in the standard BVI tennis ball. We believe that the use of this new, more localizable sound has the potential to increase the duration of rally, decrease the time and frustration involved in becoming proficient at 'finding' the ball, and generally attract and retain more players, allowing more players to experience the health and wellness benefits of tennis.

CONFLICT OF INTEREST AND FUNDING

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Types of serve stance and height of players. A study of the best servers in history

Juan Vila Pascual

Valencian Community Tennis Federation, Spain.

ABSTRACT

One of the most important performance indicators in tennis is the serve. While recognising the great relevance of this stroke, the objectives of this study were to investigate: the effect of the height of the players on the serve, the two types of stances in the serve (feet up and feet back) and, finally, to study if there was a relationship between the height of the players and the use of these stances in the serve. All this, on a sample of the 50 best servers by effectiveness in the history of the ATP. The results obtained highlighted the great importance of the height of the tennis player in the service. In addition, 72% of these best servers used the feet up stance, which implies greater advantages of this stance over the feet back stance. Finally, it was observed that the taller the players were, the more they used the feet up stance. On the other hand, the shorter the height of the players, the more frequently they used the foot back stance. Based on these results, it could help coaches to recommend one stance or the other, depending on the height and style of play of the players.

Key words: Service, height, foot up, foot back

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INTRODUCTION

Tennis is a sport in which there are many different types of strokes such as the serve, the return, the forehand, the backhand, the volley.... If we add to all these strokes that can be executed with different types of effects, directions, depths, heights, and speeds, we find that there are countless variables or ways of hitting the ball, which increases the complexity of the sport in terms of perception and response to stimuli, reading the ball, anticipation, decision-making, reaction, etc. Therefore, as has already been commented in the literature, tennis is a sport of open skills (Crespo & Miley, 1999).

Considering the large number of shot types that exist in tennis, specifically in Grand Slam tournaments, it has been observed that the strokes that occur the most during play are forehand (28%) and backhand (23%) groundstrokes, followed by first serve (19%), backhand return (12%), forehand return (9%) and second serve (7%) (Whiteside & Reid, 2017).

If we must choose the stroke that has the most influence and is the most decisive in the game, it would be the serve. In tennis, every point usually starts with a serve and a return. For this reason, having a great serve allows you to start points on serve with a considerable advantage over your opponent, as you can create space and openings that allow you to press or win the point with the next shot (serve+1). Furthermore, it is also possible to force short returns that allow the server to attack and dominate the point, or directly obtain direct points on serve (Crespo and Miley, 1999). Even, as can be seen in the work of (Whiteside and Reid, 2017), if we count the first and second serves together, the serve would be the second most frequently produced shot (26%), only behind the forehand return.

Today, the serve has acquired even more relevance, as the average number of strokes per point played is currently lower (4.7 strokes per point) according to Carboch et al. (2019). Furthermore, these authors indicated that in three of the four Grand Slams, more than 50% of all points were finished in the first 4 shots (Wimbledon 66%, Australian Open 58%, Roland Garros 52%). Therefore, considering the statistics, today's tennis would be largely made up of the serve, the return and a couple of other shots. For this reason, the service has a considerable importance in the development of the game and, as such, it is necessary to study it to achieve improvements that, even if they are minimal, can make a big difference, especially in high performance.

The serve, observed in isolation, is the only shot in our sport that depends entirely on ourselves, as the opponent does not intervene. In order to develop a great serve, it is obvious that many factors play a role, such as the correct biomechanics of

the stroke, especially the coordination of the entire kinetic chain from the bottom (the feet) to the top (the wrist), as well as the proper execution of the phases of the stroke, a precise ball toss, and a good strength-power work of both the lower and upper body to be able to hit with more speed and precision, which is very important in elite tennis (Elliot et al. 2003).

In this research we will study two factors that affect the effectiveness of the serve, one of which is not possible to influence or change in the players, which is their height. On the other factor it is possible to influence, the stance that is performed before the bending of the knees to serve. This stance can be of two types: with feet up also called ''pinpoint'' and with feet back or also called ''platform''. Thus, we will study which of them occurs more frequently in the 50 best servers in history, according to a statistic from the ATP. Finally, we will relate the variable of the height of the players with the two types of stances used. We will try to find out if there is a correlation or a more marked (statistically significant) use of one or the other type of stance in the serve, depending on the height of the players.

METHODOLOGY AND PROCEDURE

Subjects

The sample to conduct the study consisted of 50 ATP professional tennis players, both active and retired. The sample was taken from an ATP statistic dated 5 February 2021, which included the best servers in history organised in a numerical ranking, according to a service effectiveness statistic, in which the following service variables were evaluated: percentage of first serve, percentage of points won on first serve, percentage of points won on second serve, percentage of games won on serve, average number of direct serves per match and average number of double faults per match. From this service effectiveness ranking, which consisted of 735 players, the top 50 servers were selected for the study.

Material

The statistical programme Jamovi, version 1.6.13, was used. In addition, we used the statistical information collected from the 50 best servers in the history of the ATP, their profile (where their height appeared) and videos of matches of each of them in which we could observe the type of stance in the service that they used.

Analysis variables

The variables used were the quantitative variable of height, measured in metres, the qualitative variable of types of stance in the service, categorised into two groups; feet up and feet back. And finally, a qualitative variable that we called type of height, categorised into two groups; very tall (players who were taller than 1.90m) and tall (players who were shorter than 1.90m).

Procedure and statistical analysis

First, we searched for the statistics of the best servers in the history of the ATP in terms of their effectiveness in serving, selecting the top 50. Then, by entering their ATP profiles, we collected data on their height (m). Next, matches of each player, in which at least 5 serves were observed, were watched to determine, and collect the type of stance used.

Secondly, a descriptive analysis of the data obtained for the height variable of the players was carried out, calculating the mean, median, mode, standard deviation, range, maximum, minimum and percentiles for the entire sample (N=50). Next, absolute and relative frequency tables were made for the variables of height type (tall and very tall) and type of stance (feet up and feet back). Next, a contingency table was calculated by crossing the qualitative variables of type of stance and type of height, to study the degree of relationship between these two variables, using Chi square, used to analyse the dependence or independence of the variables. Afterwards, and given that in the Shapiro-Wilk normality test the distribution of the height variable (m) was different from normal (S-W $p<0.05$), the non-parametric Mann-Whitney U test was performed to compare this variable height in the two types of stance in the service and to study if there were significant differences between tennis players who use the stance of separated feet and those who use the feet up stance in the service. A significance level of $p<0.05$ (5%) was established throughout the study.

RESULTS AND DISCUSSION

Height of the 50 best servers in history

One of the objectives of this article was to study the height of the 50 best servers in history and to study its relevance in service performance. To determine this, we analysed the descriptive parameters of the height variable (m) in the sample (N=50). As can be seen in table 1, the average height of these 50 players with the highest service effectiveness is 1.94m, with the tallest players being 2.11m (maximum), both Ivo Karlovic and Reilly Opelka, who are 2nd and 3rd in this ranking of service effectiveness, only behind John Isner who is the leader of the ranking with 2.08m. And, therefore, the three players with the highest height are in the top 3 of the ranking of service effectiveness. The shortest player in the rankings is Andre Agassi at 1.80m (minimum).

Table 1

Descriptive statistics of the variable height (m) in the 50 best servers in history (ATP).

Descriptive	Height (m)
N	50
Lost	0
Mean	1.94
Median	1.93
Mode	1.96
Standard Dev	0.0657
Range	0.310
Minimum	1.80
Maximum	2.11
25 percentile	1.88
50 percentile	1.93
75 percentile	1.96

Table 2

Binomial test of frequencies of the variable type of height (very tall (+1.90m) and tall (-1.90m)).

	Level	NO.	Total	Proportion	p
Type of height	Very tall (+1.90m)	36	50	0.720	0.003
	Tall (-1.90m)	14	50	0.280	0.003

Note: H, is ratio. ≠ 0.5

In addition, it can also be observed that the most repeated height (mode) is 1.96m, found in up to 12 players of these 50. As can be seen in table 2 of frequencies, 72% of players in this classification of service effectiveness are taller than 1.90m, which is significant in relation to the 28% who are below 1.90m.

Furthermore, comparing with other studies, we note that, if we take the average height of the 50 best servers in history by effectiveness, which is, as we mentioned, at 1.94m, we observe that it is greater than the 1.88m average of the first 50 players in the ATP ranking, and substantially greater than the 1.85m average of the players from 51 to 100 in the ATP ranking (Leiting, 2015).

In a study by Dobos & Nagykáldi (2017) in elite junior male and female players, a strong positive correlation was found between the distance the ball was tossed high and the maximum speed of the ball on the serve (an indicator of serving performance), with the higher the height of the toss, both in girls and boys, the greater the speed of the serve, and this reinforces, as we already know, the importance of hitting the ball as high as possible on the serve. We can state that the greater the height of the players, the higher they will naturally hit the ball and at a greater speed (Vaverka & Cernosek, 2013), since as we observed in the study by Sánchez-Pay et al. (2019), the greater the height of the professional players, the greater service hitting speeds they achieve, thus increasing the percentage of points won with first serves and the number of direct serves. Therefore, we can say that the greater the height of the players, the greater the service performance.

In addition to achieving greater ball speed, having a greater height provides some further advantages in the serve, as the net is less of an obstacle and it is easier to overcome it, as the degree of incidence in taller players is greater, and, therefore, it is easier for them to hit from top to bottom. Also, as they have a greater degree of incidence due to their height, it is easier for them to find more angles and place the ball better, which gives them a considerable advantage to open the court with their serve and surprise their opponents (Martin, 2015).

To conclude this section, it can be stated that all the data collected allow us to note the importance of height as a clear indicator of service performance, since the greater the height, the higher the service performance parameters increase.

Frequency of the two types of stances in the best servers

The next objective of this study was to investigate the two types of stances (''feet up'' and ''feet back'') in the best servers in history, to see which is the most common and what advantages each may have.

As can be seen in tables 3 and 4, the frequency of players who serve with their feet up among the top 50 most effective servers in history is far higher than those who serve with their feet back. Specifically, there are 36 players who serve with their feet up, representing 72% of the servers, compared to 28% who serve with their feet back (14 players).

Moreover, these data are similar to those of Renoult (2007), who analysed the two stance techniques during the 2007 French Open and the results showed that 72.4 % of the players used the feet up technique. However, when studying the selection of stance according to playing style, it was observed that this percentage changed considerably, with nearly 50% of players who served and volleyed regularly or occasionally (doubles players or attacking players) using the feet back position to serve, compared to only 17% among those who never went to the net after their serve. It was found that when the player was a baseline player, he was much more likely to use feet up stance (83%), and that when the player was more likely to come up to the net the type of stance used was evened out. This proportion could be explained by the advantages provided by each type of stance, as according to Martin (2015) expert players using the feet up technique generate on average more ball speed (173 km/h vs. 166 km/h)

Table 3

Binomial test of frequencies of the variable service stances (feet up and feet back).

	Level	NO.	Total	Proportion	p
Service stance	Feet up	36	50	0.720	0.003
	Feet back	14	50	0.280	0.003

Note: H, is ratio. ≠ 0.5

Table 4

Relative frequencies of the types of stances in the 50 best servers in history (ATP).

Levels	NO.	% of total	% Cumulative
Feet up	36	72.0%	72.0%
Feet back	14	28.0%	100.0%

than with the feet back technique. This represents an average difference of 7 km/h in favour of the feet up technique. Furthermore, following this author, the feet up technique produces a greater ground reaction force than the feet back technique (2.1 times body weight compared to 1.5 times body weight). Consequently, the feet up technique allows players to impact the ball higher than the feet back technique. As we know, the higher the point of impact of the ball, the better it will be over the net, the greater the chance of improving first and second serve percentages and the more likely it is to achieve short and cross-court angles.

On the other hand, the feet back technique would provide us with two other advantages, the first being that, by having a greater base of stance, better balance and stability is achieved in the serve, making it a more appropriate and simpler stance to teach beginner players. The second advantage is that this technique, by rising less upwards than with the feet up technique, causes them to land and stabilise faster (70 ms earlier according to this study), allowing them to go up to the net faster and cover more court sooner. Therefore, this stance will generate greater success among players who tend to go up to the net more, as they will be able to cover the net sooner.

To conclude this section, considering that the majority of these 50 best servers are more modern players, where a faster, offensive and baseline tennis is played, in which the speed and power of the ball is an important factor, we can state that the advantages provided by the feet up stance are greater, and for this reason the much higher percentage of servers who use this stance (72%) could be explained.

Finally, within that 28% of players who stance with their feet back, we find players such as Pete Sampras, Boris Becker and Roger Federer who were known for their frequent use of the serve-volley tactic. This backs up the above data. All this data could help coaches to recommend the use of one or another stance depending on the player's style of play. Thus, it could be recommended, for example, the use of the feet back stance in players who use more serve and volley, as is the case of doubles players. However, in general, observing the best servers, the stance that would be most statistically effective would be the feet up stance.

Relationship of the height variable to the two types of stances

The last objective of this study was to investigate the relationship between the variable height (m), and type of height (very tall=+1.90m and tall=-1.90m) with the two types of stances, in the 50 best servers in history by effectiveness. In this way it could be known if there is a more marked use of one type of stance or another, depending on whether the players are taller.

Table 5.1 shows the contingency values that relate the service stance variables with the types of height. When players are very tall (+1.90m), they use the feet up stance more, specifically 83.3% (30/36) of servers over 1.90m use this stance. On the other hand, players who are less than 1.90m (tall), use the feet back stance more, although not in a differential way, as 57.14% (8/14) use it, compared to 42.86% (6/14) who use feet up.

Observing the Chi-square test in table 5.2, it can be noted that there is a strong dependency relationship between the variables, type of height and type of service stance. It is understood that the greater the height of the players, the more they use the feet up type of stance, and the lower their height, the more equity is found, although the feet back type is used more.

Table 5.1

Contingency table between the variables service stance (feet up and feet back) and height type (very tall and tall).

	Type of height		
Service stance	Very tall (+1.90m)	Tall (-1.90m)	Total
Feet up	30	6	36
Feet back	6	8	14
Total	36	14	50

Table 5.2

Chi-square test (X^2).

	Value	df	p
X^2	8.19	1	0.004
N	50		

If we also look at table 6 and figure 1, the average height of the servers using the feet up stance is higher (1.95m) than that of the servers using the feet back stance (1.90m). This difference in height is statistically significant ($p<0.05$), with a difference of 5 cm between the two groups. Considering the median, the difference would be even greater between the two groups as it is 8 cm higher in the group that stances with feet up. Therefore, these data would stance the previously obtained conclusion that the taller the players are, the more they use the feet up stance to serve.

Table 6.1

Non-parametric Mann-Whitney U. test.

		Statistics	df	p
Height (m)	Student's t-test	2.95	48.0	0.005
	Mann-Whitney U	136		0.011

Table 6.2

Descriptive tests for the variable height (m) of the two service stance groups (feet up and feet back) in the top 50 servers (ATP).

	Group	N	Mean	Median	SD	SE
Height (m)	Feet up	36	1.95	1.96	0.0620	0.0103
	Feet back	14	1.90	1.88	0.0584	0.0156

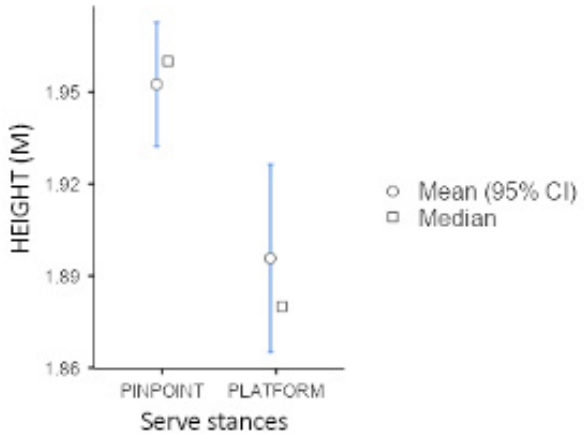

Figure 1. *Graph of the mean and median of the variable height (m), in the two service stance groups with feet up and feet back in the 50 best servers.*

To conclude this last section of the study, a possible explanation for the fact that the taller the players are, the more they use the feet up stance, could be that the taller the players are, the more they play with a tactical pattern based on powerful and aggressive strokes, basing their game above all on a powerful first serve, to try to take an early advantage and finish the point faster. For this reason, they could benefit more from the extra speed on the serve provided by the feet up stance. In addition, the stronger upward momentum after bending with this stance allows them to hit the ball at a higher point, finding better angles and placement on the serve, to move the ball further away from the opponent when opening the court. These advantages could be more beneficial to these taller servers, in a tennis as powerful as the current one, although with this stance, they have a greater loss of stability and time in repositioning after the serve, making it more difficult to get up to the net. Possibly, although it is more difficult for them to fall and stabilise themselves after the jump on the serve (an advantage provided by the stance with their feet back), they can compensate for this loss of time with a bigger stride the taller they are, and in this way, also get to the net quickly, covering the court well. Therefore, taller players would benefit more from the use of a close-footed stance than a wide-footed stance.

This conclusion is a proposal based on a tactical aspect and other biomechanical and technical factors could also be considered to favour this stance in taller players, which would be an interesting proposal for future study.

CONCLUSIONS

This study emphasises the great importance of player height as an indicator of serving performance. In addition, it allows us to know the existence of a greater predominance of the type of stance with feet up in the service compared to stance with feet back in the best servers by effectiveness in history. And it also indicates that there is a greater frequency of using this type of stance with feet up the taller the players are. This research could help coaches to recommend one type of stance or another on the serve, depending on the height and style of play of the players. Finally, this study leaves the door open to possible future studies that may find other biomechanical or technical-tactical factors that explain the greater predominance of the feet up stance the taller the players are.

CONFLICT OF INTEREST AND FUNDING

The author declares that he does not have any conflict of interest and that he did not receive any funding to conduct the research.

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Growth and maturity status of young elite and sub-elite tennis players

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ABSTRACT

The purposes of this study were to determine the growth and maturity status of young competitive tennis players and to examine their associations with national rankings. The participants were 36 male and 34 female players who competed in the U14 national team selection tournament in 2022. They were divided into three groups according to their results and entries as national players (n = 8), main draw players (n = 31), and qualifying players (n = 31). Ages at peak height velocity and growth status were calculated. Regardless of gender, the mean height and body mass percentiles of players were above the 60th centile. In girls, the results indicated that both national and main draw players were significantly more advanced in maturation ($p < 0.05$) and had higher body mass indexes ($p < 0.05$) than qualifying players. In boys, no significant differences were observed among the three groups for all variables. Correlation results showed that maturity status was the most correlated ($p < 0.01$) variable in girls. No significant relationships between rankings and other variables were obtained for boys. These results suggest that physical size and advanced maturity should be taken into consideration in the selection and identification of youth elite female tennis players.

Key words: Biological maturation, youth athletes, racket sports, talent identification.

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INTRODUCTION

The growth and maturity status of young athletes have a significant influence on their body sizes (Eisenmann et al., 2020; Malina, 2007), and individual differences in the growth and maturity status of young athletes might affect the selection since greater physical attributes may mean advantages in most sports with a few exceptions (Cumming et al., 2005; Malina, 2007; Valente-dos-Santos et al., 2012). Their impacts on the performance of youth team sports athletes are well-documented (Baxter-Jones et. al., 2020; Philippaerts et al., 2006; Torres-Unda et al., 2013; Matthys, Vaeyens, Coelho-e-Silva, Lenoir, & Philippaerts, 2012). For example, Torres-Unda et al. (2013) compared the anthropometric and physiological characteristics of elite and non-elite young basketball players and found higher results in maturity status, height, body mass, percentage of muscle mass, aerobic fitness, and countermovement jump test in favor of the elite players. However, the data on growth and maturity status in youth racket sports players are limited.

In a recent study, Coelho-e-Silva et al. (2022) examined the physical growth and biological maturation of young competitive table tennis players. Their results showed a substantial variation (between the 10th to 100th percentile) in the height and body mass of players when compared to reference values. In a similar study, Myburgh et al. (2016a) reported ranges between 50th and 90th centiles for the

mean height and body mass for young (8-17 years) elite male and female tennis players. In another study, Myburgh et al. (2016b) studied the maturity-related differences in physical fitness among young tennis players and found better results in grip strength and overhead power for the benefit of boys and girls who advanced in maturation. Conversely, no significant variations were observed in physical and performance variables between contrasting maturity groups of young female tennis players (Van Den Berg, Coetzee, & Pienaar, 2006).

The official ranking of a player is one of the major determinants of success in tennis (De Bosscher, De Knop, & Heyndels, 2003). Several earlier studies have investigated the predictors of national ranking in young tennis players. Kramer et al. (2017), for example, reported significant associations between ranking and upper body power in boys and maturity status and lower body power in girls. On the other side, findings of other recent studies indicated the technical characteristics (Kolman, Huijgen, Visscher, & Elferink-Gemser, 2021), early participation in tennis-specific practice, and weekly training volume (Söğüt, Luz, Kaya, & Altunsoy, 2019) as the most important predictors of national rankings.

In summary, current literature demonstrates fluctuating results on the correlates of ranking in junior tennis players. Besides, to the best of the authors' knowledge, no previous study has compared the physical growth and maturity status of tennis players from different competitive levels. Therefore, the purposes of this study were to determine the growth and maturity status of young elite and sub-elite tennis players and to determine their associations with national rankings.

METHODS

Participants

The sample included 36 male and 34 female young tennis players who competed in Turkish U14 National Team Selection Tournament in 2022. They were divided into three groups according to their results and entries as national players (male= 4, female= 4), main draw players (male= 16, female= 15), and qualifying players (male= 16, female= 15). The ethical approval was obtained from the Human Subjects Ethics Committee of Middle East Technical University (0294-ODTUİAEK-2022). Children and their parents or legal guardians were briefed on the measurements and purpose of the study and written informed consents were obtained.

Measurements

A portable stadiometer (Seca 213, Hamburg, Germany) was used to measure standing and sitting height to the nearest 0.1 cm. A digital weighing scale, calibrated to the nearest 0.1 kg, was utilized to measure body mass. Body mass index (BMI) was calculated by dividing body mass (kg) by the squared height (m). The physical growth status of each player was compared to a comprehensive reference database (Frisancho, 2008). Percentile and z-score values for height, body mass, and BMI were calculated. Somatic maturity was estimated through age at peak height velocity (APHV). The APHV was determined using the predictive equation proposed by Mirwald, Baxter–Jones, Bailey, and Beunen (2002). The maturity offset was calculated by subtracting the difference between the APHV and chronological age.

Statistical analysis

All data were analyzed using SPSS (v. 28.0) for Windows. Descriptive statistics (mean ± SD) were calculated for the variables. The Kruskal-Wallis Test was used to analyze the differences among groups. Mann-Whitney U tests were used to follow up pairwise comparisons and to examine the gender differences. Spearman's rank correlation coefficients were conducted to determine the associations between rankings and growth and maturity variables.

Table 1

The change in subject's physical characteristics and ranking.

	Boys	Girls	*U*	*p*
Chronological age (years)	13.5 (0.5)	13.4 (0.6)	578.5	0.693
Height (cm)	166.3 (9.2)	162.2 (6.2)	421.0	0.025
Sitting height (cm)	85.7 (5.3)	84.7 (3.5)	520.5	0.282
Body mass (kg)	53.5 (8.8)	53.6 (6.7)	609.5	0.977
BMI (kg/m2)	19.2 (1.7)	20.3 (2.0)	428.0	0.031
Height (z-scores)	0.8 (0.9)	0.6 (0.8)	532.5	0.350
Height (percentiles)	71.1 (26.9)	67.7 (24.1)	533.0	0.353
Body mass (z-scores)	0.3 (0.6)	0.5 (0.5)	484.5	0.134
Body mass (percentiles)	60.8 (20.2)	68.1 (14.7)	483.5	0.131
BMI (z-scores)	-0.01 (0.5)	0.2 (0.5)	467.0	0.088
BMI (percentiles)	49.5 (17.1)	57.3 (16.1)	470.0	0.095
APHV (years)	13.6 (0.6)	12.0 (0.4)	7.500	< 0.001
Maturity offset (years)	-0.1 (0.9)	1.4 (0.6)	70.5	< 0.001

RESULTS

The descriptive statistics and gender differences are presented in Table 1. The results indicated significant differences in body height, BMI, APHV, and maturity offset. Boys were found to be significantly taller and have lower BMI values than girls. On the other hand, girls were significantly more advanced in maturation than boys.

The descriptive statistics of male players and the results for the Kruskal-Wallis Test are given in Table 2. The results revealed no significant differences among the three groups for all parameters.

The descriptive statistics of female players and the results for the Kruskal-Wallis Test are represented in Table 3. The results indicated that both national and main draw players were significantly older (national vs qualifying: U = 4.000, p = 0.009; main draw vs qualifying: U = 41.500, p = 0.003) and more advanced in maturation (national vs qualifying: U = 8.000, p = 0.028; main draw vs qualifying: U = 48.500, p = 0.008) and had higher BMI (national vs qualifying: U = 7.000, p = 0.021; main draw vs qualifying: U = 65.500, p = 0.049) values than qualifying players. Besides main draw players had significantly greater body mass than qualifying players (U = 56.000, p = 0.019). No significant differences were observed among the three groups for other variables.

Table 2

Descriptive statistics of boys and the results for Kruskal-Wallis Test.

	National players	Main draw players	Qualifying players	*H*	*p*
Chronological age (years)	13.6 (0.5)	13.6 (0.4)	13.3 (0.6)	4.063	0.131
Height (cm)	165.9 (7.9)	167.3 (8.7)	165.3 (10.4)	0.328	0.849
Sitting height (cm)	84.8 (5.1)	86.9 (4.8)	84.6 (5.9)	1.664	0.435
Body mass (kg)	54.3 (8.4)	54.5 (9.2)	52.2 (8.9)	0.491	0.782
BMI (kg/m2)	19.6 (1.4)	19.4 (1.9)	18.9 (1.5)	0.163	0.922
Height (z-scores)	0.6 (1.1)	0.8 (0.9)	0.8 (1.0)	0.142	0.931
Height (percentiles)	67.1 (33.9)	71.8 (28.1)	71.3 (25.9)	0.153	0.926
Body mass (z-scores)	0.3 (0.6)	0.3 (0.6)	0.3 (0.6)	0.038	0.981
Body mass (percentiles)	61.9 (21.7)	61.7 (20.7)	59.6 (20.7)	0.041	0.980
BMI (z-scores)	0.1 (0.4)	0.001 (0.5)	-0.04 (0.5)	0.307	0.858
BMI (percentiles)	53.2 (14.5)	49.3 (17.7)	48.8 (17.9)	0.307	0.858
APHV (years)	13.7 (0.7)	13.5 (0.6)	13.6 (0.6)	0.598	0.742
Maturity offset (years)	-0.1 (0.8)	0.1 (0.8)	-0.3 (0.9)	1.607	0.448

Table 3

Descriptive statistics of girls and the results for Kruskal-Wallis Test.

	National players	Main draw players	Qualifying players	*H*	*p*
Chronological age (years)	14.0 (0.1)	13.6 (0.5)	13.0 (0.5)	12.814	0.002
Height (cm)	160.5 (3.5)	163.5 (5.4)	161.3 (7.4)	1.027	0.599
Sitting height (cm)	84.5 (2.3)	85.4 (3.3)	84.1 (3.9)	1.157	0.561
Body mass (kg)	55.8 (3.3)	55.5 (5.5)	51.1 (7.8)	6.813	0.033
BMI (kg/m2)	21.7 (1.8)	20.8 (1.9)	19.5 (1.9)	6.814	0.033
Height (z-scores)	0.1 (0.5)	0.7 (0.8)	0.7 (0.9)	1.383	0.501
Height (percentiles)	55.4 (18.5)	70.3 (22.7)	68.5 (27.0)	1.383	0.501
Body mass (z-scores)	0.6 (0.2)	0.6 (0.4)	0.4 (0.5)	1.466	0.480
Body mass (percentiles)	71.2 (8.4)	71.3 (13.9)	64.1 (16.3)	1.466	0.480
BMI (z-scores)	0.5 (0.4)	0.3 (0.5)	0.1 (0.4)	3.111	0.211
BMI (percentiles)	66.7 (13.4)	59.9 (17.7)	52.3 (14.1)	3.066	0.216
APHV (years)	12.3 (0.2)	12.0 (0.4)	11.9 (0.4)	3.175	0.204
Maturity offset (years)	1.7 (0.3)	1.6 (0.4)	1.1 (0.6)	8.950	0.011

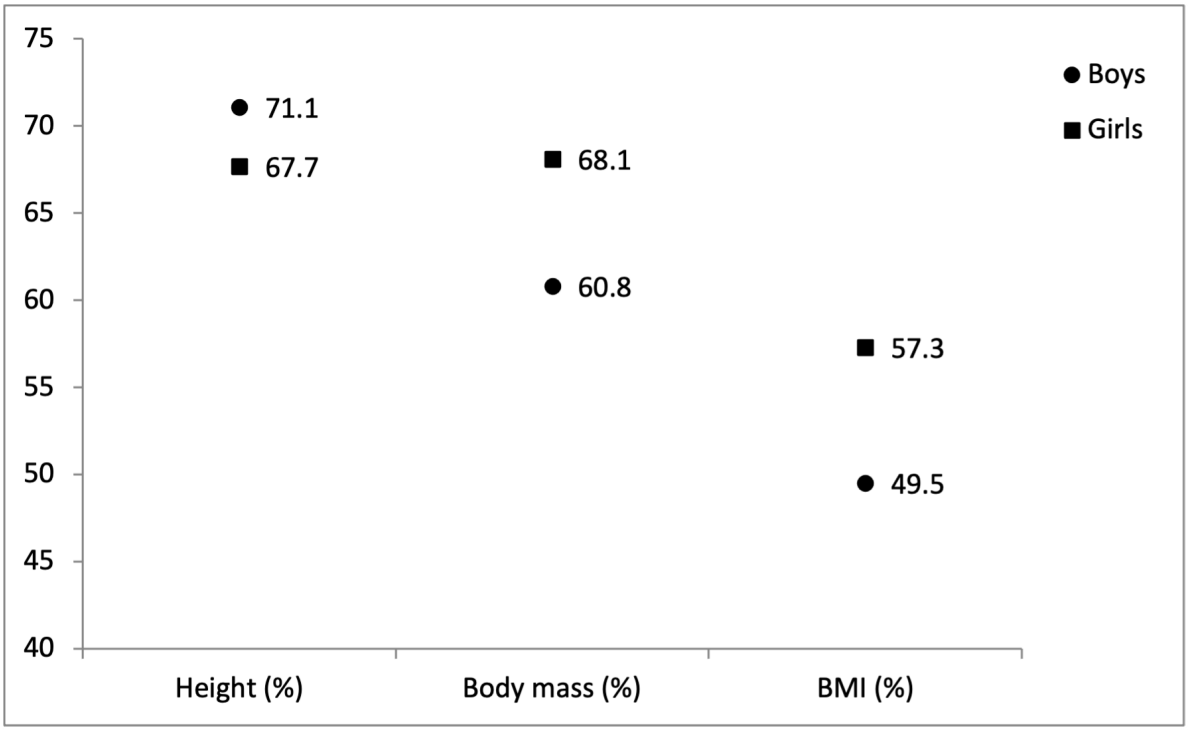

Figure 1. *The mean height, body mass, and BMI percentiles of boys and girls.*

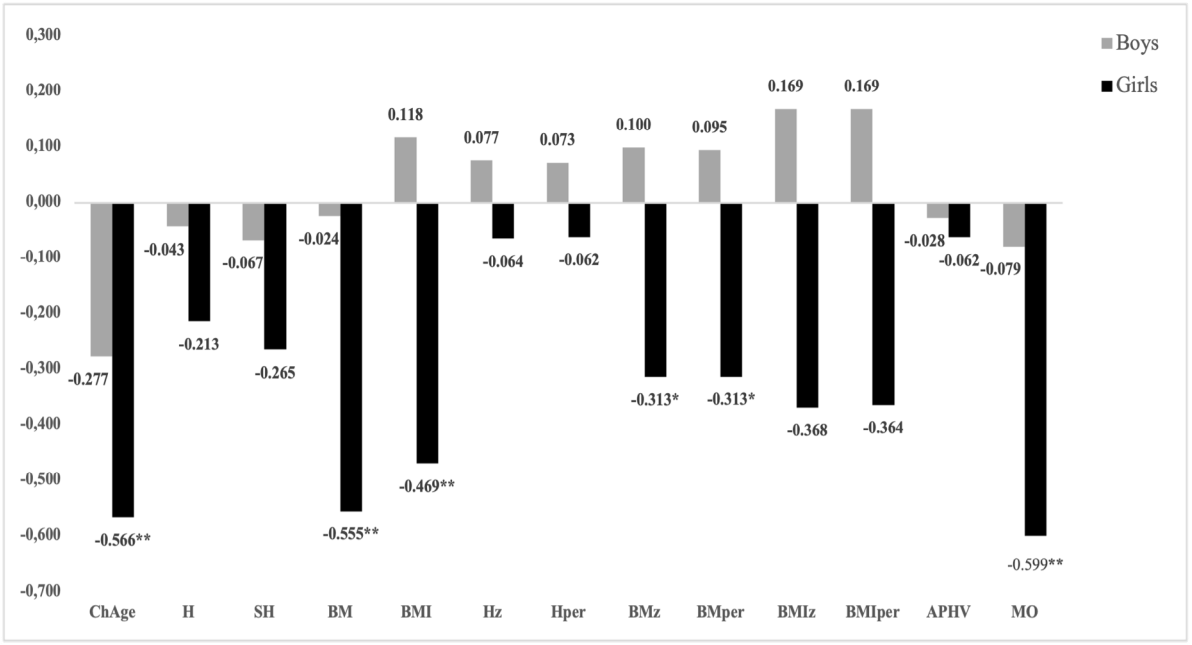

Figure 2. *Correlation results between ranking and other variables by gender.*

ChAge= chronological age, H= height, SH= sitting height, BM= body mass, BMI= body mass index, Hz= height z score, Hper= height percentile, BMz= body mass z score, BMper= body mass percentile, BMIz= body mass index z score, BMIper= body mass index percentile, APHV= age at peak height velocity, MO= maturity offset.

** p<0.05, ** p<0.01*

The mean body height, body mass, and BMI percentiles of male and female players are given in Figure 1. Regardless of gender, height, and body mass percentiles of players were above the 60th centile. The heights, body masses, and BMIs of male players ranged between 17th - 99th, 14th - 94th, and 14th - 93rd centiles, respectively. In girls, they fluctuated between 13th - 99th, 34th - 95th, and 31st - 87th centiles.

The correlations between national rankings and other parameters for boys and girls are presented in Figure 2. In girls, the results showed significant associations between ranking and chronological age ($r_s(32) = -0.566$, $p = 0.001$), body mass ($r_s(32) = -0.555$, $p = 0.001$), BMI ($r_s(32) = -0.469$, $p = 0.005$), BMI z score ($r_s(32) = -0.368$, $p = 0.032$), BMI percentile ($r_s(32) = -0.364$, $p = 0.034$), maturity offset ($r_s(32) = -0.599$, $p = 0.001$). In boys, no significant relationships between ranking and other variables were attained.

DISCUSSION

This cross-sectional study aimed to determine the growth and maturity status of young competitive tennis players and to examine their associations with national rankings. The results revealed gender differences in various parameters. Boys were found to be significantly taller and had lower BMI values than girls. On the other hand, girls were found to be more advanced in maturation than boys. The disparities in maturity status were also observed from the findings of previous studies (Kramer et. al., 2017; Söğüt et al., 2019). This result may be explained by the timing of the growth spurt, as girls achieve their peak height approximately two years earlier than boys do (Beunen & Malina, 1996; Malina et al., 2004; Sherar et al., 2007).

Another notable finding was that the mean height, body mass, and BMI percentiles of both boys and girls were above the 50th percentile when compared to age- and gender-matched normative references, except for the BMI percentile in boys (49.5). These results are in line with the findings of Baxter-Jones et al. (1995), Erlandson et al., (2008), Myburgh et al. (2016), and Söğüt et al. (2019). It seems that there is a tendency for greater body size among young competitive tennis players.

The results showed no significant differences among the three groups for all parameters for boys. On the other hand, for girls, both national and main draw players were significantly more advanced in maturation and had higher BMI values than qualifying players. Besides, the results for girls showed significant associations between ranking and maturity offset and BMI parameters, whereas no significant associations were observed for boys. These findings are in agreement with previous studies (Kramer et. al., 2017; Söğüt et al., 2019). Their results indicated significant relationships between national rankings and the percentage of the predicted adult stature and APHV in U12 and U13 female players, respectively. It might be concluded that maturity status has a crucial role in tennis performance for girls competing in this age category.

This study is subject to two main limitations. First, the sample was limited to U14 tennis players in a national team selection tournament. Second, tactical, technical, and psychological performance indicators were not included in this study. Unierzyski (2002) indicates that experience-related parameters might be decisive factors in actual tennis performance in junior tennis; however, they might not affect tennis performance on the professional level. Therefore, future studies are suggested to expand their scope by including consecutive age groups and other possible performance indicators.

In conclusion, this study aimed to add new insight to the scarce literature on the growth and maturity status of young competitive tennis players and their influences on actual tennis performance. The results demonstrated maturity-associated differences in favor of the elite girls. The findings suggest that physical size and advanced maturity should be taken into consideration in the selection and identification of youth elite female tennis players.

CONFLICT OF INTEREST 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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Review of ITF-Approved Player Analysis Technology (PAT)

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ABSTRACT

In this article an instrumental review is carried out from a technical/tactical point of view of measuring devices and apparatus applied to tennis. More specifically, a review of the current panorama of the "Player Analysis Technology" (PAT) approved by the ITF (International Tennis Federation) is proposed. The rationale would be the growing importance and application that they are acquiring since the approval of rule 31 by the ITF that allows the use of these PATs in tournaments.

Key words: Player Analysis Technology, International Tennis Federation, new technologies, training.

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INTRODUCTION

Tennis is a sport with specific game characteristics and physical demands. As indicated by Sanz Rivas et al. (2009) "the tennis match is characterised by intermittent exercise, alternating short sets (4-10 seconds) of high intensity exercises and short sets (10-20 seconds) of recovery interrupted by several rest periods of longer duration (60-90 seconds)". That is why in the teaching-learning process of tennis it is very important to know how to quantify and deal with the loads at a technical-tactical, physical, and mental level. For this reason, there has been an increasing use of new analysis tools and their application in the process of game development, which provides evidence of the technical level in real time, allows comparison between different training sessions or matches and the data collected can be shared and communicated on different platforms (Quinlan, 2013).

In 2006, the Hawk-Eye was officially introduced at the Miami, NASDAW-100 ATP Open tournament in Miami, which set a revolutionary technological precedent within the sport that served as a precursor to many other technological innovations (Gellard et al., 2018) and which has proven to be a very useful tool for both chair umpires in their work and for the player's coaching staff as a means of assessing player performance (Baodong, 2014; Gellard et al., 2018).

As a consequence of the implementation of Hawk-Eye, in 2014 the ITF incorporated Rule 31 into its regulations which allows players to wear "smart" equipment in tournaments. Devices placed around the court to track the player are also permitted. Only ITF-approved PAT devices are allowed during competition (Tennis Industry, 2014; ITF, 2019). This Rule 31 is supplemented by Appendix III of the ITF Rules and Regulations which defines "Player Analysis Technology" as any equipment that can perform the functions of recording, storing, transmitting, analysing, and communicating with the player during a match. Such information must be accessible to the player in accordance with Rule 30 (coaching) and Appendix II (The Racket).

This Player Analysis Technology can measure and compare a wide variety of time-based, performance-related variables divided into three groups in relation to:

- **Player.** The primary variables are position and acceleration; stride length and frequency; heart rate; and sweat rate. Secondary variables refer to total and average distance travelled; work-rate; and sweat rate (Reilly, 2005; Ugarte, 2014) and energy consumption. As tertiary variables, an example would be fatigue.
- **Hitting.** Primary variables are the position and orientation of the racket. Secondary variables are the point of impact of the racket with the ball; the type of stroke (serve, volley, forehand, backhand), type of spin (slice, topspin); and power (of the racket).
- **Ball.** The primary variable is position. Secondary variables comprise trajectory; speed; and outcome (in or out). The tertiary variables consist of outcome; match time; and match simulation.

These technologies have been submitted by a total of 19 companies from 14 different countries, including Austria, Czech Republic, Finland, France, Germany, Poland, Slovenia, Spain, Switzerland, and Great Britain in Europe; Hong Kong, Israel, and Japan in Asia; and the United States in America. Finland, France, the UK are home to two developers and only the US has three companies on this list.

This article presents the different TAPs approved to date by the ITF, grouped by category. In addition, some of their characteristics, such as the variables that these devices are capable of analysing, will be discussed in more detail.

METHODOLOGY

For the procedural review of these devices, the list of PATs has been deepened in January 2022 with a total of 28 products. In the document "Player Analysis Technology Overview" (ITF, 2019) establishes three distinct categories:

- **Integrated equipment.** Equipment that can be worn or used on court by players. This includes clothing, wearables; tennis-specific equipment (e.g., rackets); and non-tennis specific equipment (e.g., heart rate monitors, activity monitors).
- **Remote equipment.** Any device not carried or used by the player (e.g., camera-based player tracking systems).
- **Auxiliary equipment.** Equipment that does not record player performance information but can perform any of the other PAT functions, such as tablets, mobile phones and the software that operates on these devices.

Disregarding the ancillary equipment that may be required for each of these approved technologies, we find that there are 19 in the first group and 9 in the second. A separate grouping will be made based on the type of device technology.

RESULTS AND DISCUSSION

Table 1 gives an initial classification of these devices according to the type of equipment. Of the total of 28, 19 are distinguished as integrated equipment and 9 as remote equipment.

Table 1

Grouping of ITF-approved PAT teams based on equipment type.

INTEGRATED TEAM	REMOTE EQUIPMENT
Armbeep	Bigbow Camera System
Artengo Personal Coach	Billie Jean King Cup match insights App
Babolat Play Aeropro Drive	eyes3 For Tennis Pro
Babolat Play Pure Aero	Flightscope Player Tracking
Babolat Play Pure Drive	Foxtenn Diamond Player Pro-Performance Court
Babolat Play Pure Drive V2	Hawk-Eye
Babolat Play Pure Drive Lite	Playsight Smart Court
Babolat Pop	Wingfield
Bigbow Basic Sensor	Zennis
Bigbow Champion Sensor	
Catapult Optimeye S5	
Catapult Vector	
Firstbeat	
Head Tennis Sensor	
Kitris Kit	
Kitris Kit Bia	
Sony Smart Tennis Sensor	
Whoop	
Zepp Tennis	

A second distinction will be made based on the type of solution. Thus, a distinction will be made between racket sensors (integrated in the racket as standard, integrated in the racket, in the handle, in the strings, on the wrist); wearable sensors other than wrist sensors; umpiring systems, tracking systems, statistical applications and game analysis applications; "smart courts" systems; score trackers either on a wristband, an auxiliary device or specific hardware on court and sports smartwatches or compatible bracelets. Based on this distinction, the different devices will be presented in groups.

Among the different racquet sensors is the Artengo Personal Coach (2014) (Figure 1), developed in France, which consists of two separately available devices, the first of which is a 24-gram weight sensor, adjustable to all types of racquets (ITF, 2019). The information can be seen after the training session on a computer or in real time on the second of the two devices, a watch which, in addition to the tennis functions in training or match mode, can be used as a heart rate monitor to measure heart rate as well (ITF, 2019). (Diario, 2013; Europa Press, 2013; Tennis-Technology, 2020a). Significantly, however, it is currently not available in Decathlon shops, nor is it available in the Artengo catalogue.

Figure 1. *Artengo Personal Coach (2014).*

Sony (Japan), on the other hand, brought to market another smart sensor, its Sony Smart Tennis Sensor (2014) (Figure 2), for rackets that can be attached to the end of the grip of Wilson, Yonex, Prince and Head rackets (Sacristán, 2015; Tennis-Technology, 2020c; Vts-tennis, n. d.).

Figure 2. *Sony Smart Tennis Sensor (2014).*

For its part, Babolat, together with its development partner PIQ Sport Intelligence (Businesswire, 2016) marketed the first smart racquet, the Babolat Play Pure Drive (2014) (Figure 3), which comes standard with a built-in smart device. (Dominik, 2020; Tennis-Technology, 2020b). Babolat is expanding its smart racket portfolio in 2016 with the new version of its previous model, the Babolat Play Pure Drive V2, as well as the new Babolat Play Aeropro Drive, Babolat Play Pure Aero and Babolat Play Pure Drive Lite. To point out that from the ITF website (ITF, 2019) you can download the different certificates of approval but not the reports, you can only download the report of the first model.

Figure 3. *Babolat Play Pure Drive (2014).*

ZEPP Labs, USA, developed the third ITF-approved smart sensor (2015), adjustable to the end of the racket's grip like the Sony Smart Tennis Sensor, the ZEPP Tennis (Tennis-Technology, 2020d) (Figure 4). Today, however, ZEPP has stopped marketing this sensor and offers only its upgrade, which does not appear on the ITF list (Europa Press, 2017; GizTab, 2017; ZEPP Labs, n. d.-b). Add informatively that this company offers other possibilities within this line of smart sports equipment for other sports such as golf, tennis or football that could be perfectly adapted to the practice of tennis. (ZEPP Labs, n.d.-a).

Figure 4. *ZEPP Tennis (Tennis-Technology, 2020d).*

The Czech company Proavis S.R.O. presented two smart devices in 2016 that are primarily intended to be attached to the end of the racquet handle but are also adaptable to other types of sports equipment: the Bigbow Basic Sensor and the Bigbow Champion Sensor (Figure 5). The main difference between the two lies in the connectivity for data transmission.

Figure 5. *Bigbow Basic Sensor.*

Only one new device is approved in 2018, the Head Tennis Sensor (Figure 6) from Austrian Head developed by Zepp. (Best tennis sensors (updated in 2022!), 2020; Tennis Sensor - HEAD, n. d.; Top 5 best tennis sensors 2020 - track and analyze, 2020).

Figure 6. *Head Tennis Sensor.*

Among the wearable devices, the first device to be approved was the Kitris Kit (Figure 7) from Kitris AG, Switzerland, which is a wrist device that serves as a scoreboard, audio record of how points were won and lost, and voice recorder for capturing mid-game notes. (KITRIS, n. d.). To ensure that this device does not violate ITF Rule 30, which prohibits on-court coaching, on-court recording and notes cannot be accessed. (Tennishead, n. d.).

Figure 7. *Kitris Kit.*

In 2015, Kitris AG introduced an upgrade to their device, the Kitris Kit Bia (Figure 8). Currently, only this upgrade is marketed on their website under the name Kitris Kit (KITRIS AG, n. d.-a). From what they advertise, it seems that Kitris has refocused their offer from tennis to sport in general by offering an easy to install "plug & play" system offering a product similar to Playsight Smart Court (KITRIS AG, n. d.-b).

Figure 8. *Kitris Kit Bia.*

For its part, Babolat presented a smart wrist sensor, the Babolat Pop (2015) (Figure 9) that can be worn either under a normal wristband or sheathed inside an accessory wristband that comes with it (Private Sport Shop, n. d.; VTS Tennis, n. d.).

Figure 9. *Babolat Pop.*

In 2019, the Slovenian company Biometrik D.O.O. Armbeep was approved. (ITF, 2019; Tennis analytic system, 2020) (Figure 10).

Figure 10. *Armbeep*

In the same year, two new devices arrived from Catapult PTY. Ltd (Figure 11). Catapult introduced its Catapult Optimeye S5 sensors (Fernández-García & Torres-Luque, 2018) and Catapult Vector, which are worn inside a bib worn by the athlete. The data is captured by a receiver and can be viewed through the Catapult OpenField software on an auxiliary device in both cases or also through a smartwatch or smartphone with the Catapult Vector app in the case of the Catapult Vector. The Catapult company is not limited to the tennis market and offers several other products easily applicable to racquet sports that are not listed by ITF (Catapult, n. d.; Catapult Support, n. d.).

Figure 11. *Catapult PTY. Ltd.*

In 2020, Finland's Firstbeat Technologies OY unveiled its Firstbeat device (Figure 12). Unlike the Catapult sensors, this one is integrated with a chest strap. (ITF, 2019; You have it in you, n. d.). Data can be accessed through two apps in different ways. The Live app allows coaches to view and obtain data from multiple players simultaneously. (Introducing Firstbeat Sports Sensor and Live app, n. d.). The Sports app app (Firstbeat Sports Standard + Sensor, n. d.) allows players to log in individually to a personal account and access their own coaching information (ITF, 2019).

Figure 12. *Firstbeat.*

Also in 2020, the US-based Whoop Inc. certified Whoop 3.0 (Figure 13) (ITF, 2019). Currently, the company markets version 4.0, which is not registered in the list (WHOOP, n. d.).

Figure 13. *Whoop 3.0.*

Within the refereeing systems, in 2013, the Hawk-Eye (40) (Figure 14) (Great Britain), consisting of a system of multiple video cameras (8-10), personal computer, two-way radio with intercom panel, in-stadium display and auxiliary device (smartphone) was approved (ITF, 2019).

Figure 14. *Hawk-Eye (40).*

In 2017, Foxtenn BegreenS.L. introduced the first and so far only Spanish smart technology applied to tennis with its Foxtenn Diamond Player Pro-Performance Court system (Figure 15) which uses multiple high-speed cameras and high-frequency laser scanners placed around the court connected to a server to capture player and ball trajectories (Foxtenn Diamond System, n. d.; ITF, 2019). The system can optionally be connected to audio output and data can be displayed through auxiliary devices. Compared to the Hawk-Eye, it allows to visualise the live spot and the impact of the ball with the ground with millimetre accuracy instead of working with triangulations via cameras (Rigueira, 2017; Serras, 2017). Their website differentiates two types of solutions for the Foxtenn Diamond system today, one focused on tournaments and professional players and another for academies and players in training (Foxtenn Diamond System, n. d.).

Figure 15. *Foxtenn.*

The Flightscope Player Tracking (Figure 16) from Poland's FlightScope SP Z.O.O., 2017 also became the third electronic line arbitration system to meet the criteria set by the committee (About FlightScope Tennis, n. d.; Ramos, 2020). The software reconstructs player positions in three dimensions from multiple camera images; player position data is used to generate coaching information including distance travelled, player speeds and court coverage and can be transmitted to the stadium screen, television or other devices via the internet (ITF, 2019). It should be mentioned firstly that this company also uses its technology in other sports; and secondly that the listed link does not work and that they seem to be implementing a new solution with this technology for the current year 2022 (FlightScope tennis, 2022).

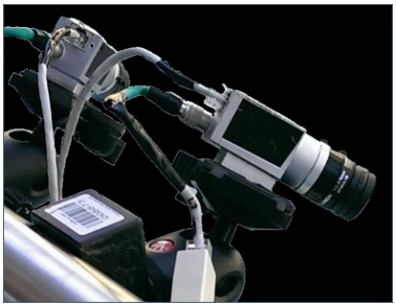

Figure 16. *FlightScope Player Tracking.*

Among the "smart courts" solutions is the Playsight Smart Court (PlaySight, n. d.) (Figure 17) developed by Playsight Interactive LTD in Israel (2014), a fully automated on-court monitoring system that offers line shot umpiring, live streaming, multi-angle video replays with the possibility of video analysis and detailed game statistics offered in an interactive court-side display unit (Gellard et al., 2018) which turns the court into something we could call a "smart court".

Figure 17. *Playsight Smart Court.*

In 2019, the Wingfield from the German company Wingfield GmbH is approved, which is another integrated solution that turns the tennis court into a "smart court" (ITF, 2019; Making tennis smart, n. d.). This system consists of two cameras on both sides of the net and another one on one of the back courts connected to a kiosk at the side of the court, next to the net. The software reconstructs the players' positions and ball trajectories in three dimensions from the incoming images. The useful training information is not displayed on the box, but on the Wingfield App via an auxiliary device.

As tracking systems, 2016 saw the introduction of the Bigbow

Figure 18. *Making tennis Smart.*

Camera System (Figure 19), a system composed of multiple smart cameras connected to a server using the BigBow Manager software which displays the position of the ball and players in three dimensions, ball speed and identification of ball impacts (racket and court).

Figure 19. *Bigbow Camera System.*

In 2017 the eponymous Finnish company presented its Zenniz device (Zenniz, n. d.) (Figure 20) consisting of multiple microphones placed around the court connected to a central unit that houses a touchscreen user display and speaker that allows the ball trajectories to be reconstructed in three dimensions. The information displayed on the screen depends on the selected mode (ITF, 2019). From what they present on their website, they seem to have evolved the system to offer a kind of "smart court" similar to what is offered by Play Sight by now integrating the screen into a kiosk at the court side and incorporating cameras also to offer video analysis (Zenniz, n. d.). Apart from offering a line refereeing system and live statistics it also offers interactive training exercises (Zenniz, n. d.). However, these improvements are not reflected in the official list of approved PATs.

Figure 20. *Zenniz.*

From Hong Kong comes the Eyes3 For Tennis Pro system from Infinite Cube (Figure 21), a portable electronic VAR and line umpiring system (Eyes3 Fair Play technologies for sports, n.d.; ITF, 2019). The difference between this system and the rest is that no specific hardware is needed and it can be quickly set up on the court and at a lower cost; however, it requires auxiliary devices, at least eight mobile phones as image capture devices and another as a control device (Eyes3 Fair Play technologies for sports, n.d.; ITF, 2019). A negative aspect is that they only work on Apple operating systems (ITF, 2019).

Figure 21. *Eyes3 For Tennis Pro.*

Finally, as a last PAT, in 2021 US giant Microsoft released its Billie Jean King Cup Match insights App (Figure 22) that combines live scores with ball/player tracking data to provide near real-time coaching information to an ancillary device (Billie Jean King Cup- Microsoft powers data and insight at Billie Jean King Cup Finals, n.d.; ITF, 2019).

Figure 22. *Billie Jean King Cup Match Insights App.*

This results in the following grouping.

Table 2

Grouping of ITF-approved PAT teams based on solution type.

Integrated equipment			Remote equipment		
Racket sensors	**Wearable devices**	**Arbitration systems**	**"Smart court" solutions**	**Tracking systems**	**Applications**
Artengo Personal Coach	Kitris Kit	Hawk-Eye	Playsight Smart Court	Bigbow Camera System	Billie Jean King Cup Match Insights App
Sony Smart Tennis Sensor	Kitris Kit Bia	Foxtenn Diamond Player Pro-Performance Court	Wingfield	Zenniz	
Babolat Play Pure Drive	Babolat Pop	Flightscope Player Tracking		Eyes3 For Tennis Pro	
Babolat Play Pure Drive V2	Armbeep				
Babolat Play Aeropro Drive	Catapult Optimeye S5				
Babolat Play Pure Aero	Catapult Vector				
Babolat Play Pure Drive Lite	Firstbeat				
ZEPP Tennis	Whoop 3.0				
Bigbow Basic Sensor					
Bigbow Champion Sensor					
Head Tennis Sensor					

First, it should be mentioned that the grouping presented based on the type of solution is based on the main function of this technology, and it may be the case that the same product has functions of one or other type of solution.

On the other hand, to analyse these devices in the current landscape, it is necessary to highlight the effects of the COVID-19 pandemic that have affected this niche as well. As mentioned above, Artengo stopped marketing its system. Babolat announced the cessation of sales of its Play and Pop smart devices (PLAY & POP - Discontinuation of connected services, n. d.) due to the bankruptcy of its development partner PIQ Sport Intelligence (PIQ adventure just ended, n. d.). FlightScope was acquired by IMGArena in 2021 (Sports services, 2021) which makes the above mentioned change of domain and product vision understandable. It seems that Proavis s.r.o. also undergoes some kind of a reshuffle, which would make it understandable that the domain or its products can no longer be found for sale. (PROAVIS s.r.o. , Praha IČO 25671227 - Obchodní rejstřík firem, n. d.).

Another factor to consider is the product development itself, which may lead the company to replace its product with another product or to integrate it into another type of solution. As mentioned, this has happened with the original Kitris Kit model which has been replaced by the later Kitris Kit Bia under the name Kitris Kit. Zepp, for its part, is marketing the second version of its racquet sensor (having stopped the first one) as well as developing the Head one. Also mentioned, Zenniz seems to have incorporated the use of cameras for a reorientation of its product, although it seems that it will continue to market the approved system. Finally, Whoop has switched to marketing its Whoop 4.0 device, making Whoop 3.0 obsolete. As a result, at the beginning of 2022, only fifteen of the twenty-eight registered products are still on the market, although we could increase this figure to seventeen if we consider the new unregistered models of the Whoop and Zepp products.

CONCLUSIONS

The conclusions of this work are as follows: Firstly, the main game characteristics and specific physical demands of tennis are identified, highlighting the importance in the tennis teaching-learning process of knowing how to quantify and work the loads at a technical-tactical-physical-mental level. In addition, the official introduction of the Hawk-Eye in the Miami tournament and the consequent drafting of Rule 31 in the ITF regulations that allows players to use "intelligent" equipment in official tournaments is also discussed. The different player analysis technologies that have been approved by the ITF up to the beginning of 2022 are also analysed, with a total of 28 of them, 19 as integrated equipment and 9 as remote equipment. It should be noted that only fifteen of the twenty-eight registered are still on the market, although there would be seventeen if the new unregistered models of two of these devices were to be considered.

On the other hand, these technologies include racket sensors (integrated in the racket as standard, integrated in the racket, in the fist, in the strings, on the wrist); other wearable sensors apart from wrist sensors; umpiring systems, tracking systems,

statistical applications and game analysis applications; smart court systems; scoreboards either by wristband, auxiliary device or specific hardware on the court and compatible sports smartwatches or bracelets. Likewise, it is highlighted that the use of smart devices in tennis can be of great help to the training process and that their choice will depend fundamentally on the parameters to be monitored and the target audience of the tennis player. Likewise, some direct effects caused by the COVID-19 pandemic can be observed. After the closure of the Babolat Play line, smart rackets are no longer available, although there is still a good supply of smart sensors. Also, some market trends towards offering integrated systems, smart courts, and diversification of solutions to also cover other sports are evident.

A possible extension and complementary avenue would be to review other PAT solutions that are not on the ITF list. Another possible avenue for expansion would be to analyse the devices according to the analysis variables. A proposal to liberalise and promote the use of racket sensors would be the standardisation of the hole at the end of the racket handle, which would make it easier to use the sensor of the player's choice on any racket. With a target group of non-professional users in mind, new integrated systems could be investigated with the minimum specific hardware that would encompass an integrated plug and play solution, a smart court with an on-court referee system and scoreboard and/or auxiliary device, compatible with sports smartwatch devices, chest straps and racket sensors and connection to some kind of platform for statistical analysis, video analysis of the player and online social platform and also the possibility of carrying out fitness or off-court training. Another possible proposal for non-professional users would be the creation of an application for smartwatches at a relatively low cost and offering what tennis players in training or regular players demand.

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The author declares that he has no conflict of interest and that he did not receive any funding to carry out the research.

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Storytelling and tennis: Coaching, marketing and selling the game

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ABSTRACT
Storytelling, understood as the art of sharing stories that support a certain narrative, has evolved into an extremely useful tool for conveying the message appropriate to a given purpose. It is used by organisations and individuals and applied to many contexts that range from politics to business, arts, or sports. The purpose of this article is to reflect on the main characteristics of this phenomena including its definition, importance, origin, evolution but, most importantly, its application to different tennis contexts.

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INTRODUCTION

What is storytelling and why it's important?

Storytelling, or the "art of storytelling", is a technique that refers to the process of sharing stories that are effective fictions and useful narratives. Its relevance has been noted by authors such, among others, Carville and Begala (2003; 12) who stated that "If you don't communicate with stories, you don't communicate".

It is an extremely efficient technique as it has been shown that human beings deal with information in a narrative form. Since the dawn of time, mankind has passed on its experiences and beliefs through stories and narratives that have included heroes, heroines, gods, myths, imaginary characters, and unbelievable events. Peoples, tribes, and communities in all times, places and societies have built their identities on the stories that explain their origins. Common stories and individual narratives of those who have excelled by their deeds (Cobley, 2013).

Some authors consider the human being a "storytelling animal" a "homo fictus" or fiction man and see fictions and stories as tools that make us humans because we are addicted to them (Gottschall, 2012).

When did it appear and how did it evolve?

Telling stories has been considered by authors such as Barthes (1966) as one of the great categories of knowledge which has been used to understand and order the world by clarifying the experience of humanity since its inception. However, not until late-1960s, that it was introduced a new discipline called "narratology" or the science of stories (Todorov, 1969) as a discipline to explain how stories could be a powerful tool to create reality.

It was initially restricted to the children's world and to be used in the leisure time. However, it gradually evolved and spread over to a wider context: culture, politics, business, and sport. Its key principle is that all messages, to be effective, should adopt a narrative form. By mid-1980s, the birth of a new era in communication was identified: the "narrative era" (Fisher, 1984).

In what contexts and how has it been used?

Since its beginnings, it has been used practically everywhere in increasingly sophisticated ways. The world of management and marketing, as well as the world of politics are clear examples of widespread uses of storytelling. It is spreading into unexpected terrain. It is a form of discourse that is being imposed in all sectors of society. Reality is now enveloped in a narrative network that filters perceptions and stimulates useful emotions. For instance, in the case of education, storytelling is used to build emotional, social, and academic skills across the primary curriculum (Fox, 2006). This author

reinforces the importance of stories and storytelling as well as the role of children as storytellers that can create unique stories that foster thinking skills, reflection, and emotional literacy.

Storytelling has very different applications, from oral storytelling practiced by griots and storytellers to digital storytelling that practices virtual immersion in multi-sensory universes and involves highly elaborate staging. These are compelling and captivating stories that offer plausible explanations. Storytelling establishes narrative pathways that lead individuals to identify with models and adhere to protocols. Formal discourse appeals to emotions more than their opinions, with narrative illustrations that speak to the listener's heart more than reason. Anecdotes have replaced discourse statistics. And the narrator's fiction replaced reality.

For what purpose?

It can be used to educate and train people, but it is also used as a technique of communication, control, and power. It is used by educators as a teaching method and by psychologists as a trauma healing tool. It is an answer to the meaning crisis in organizations, a propaganda tool, an immersion mechanism, a tool for profiling people, a technology for visualizing information, and a terrifying weapon of disinformation.

As Si (2016, p. 224) stated: "Narrative has always been an important part of human communication. We tell stories not only for entertainment, but also for sharing information and influencing others".

Why is it successful?

How can this impact of storytelling be explained, and why is storytelling considered the new paradigm of communication? Generally speaking, there are three kinds of reasons: The first is the emotional nature of the individual, the second is the talent of the leader, and the third attributes this change to the "modern psyche" that we call postmodern. A small narrative mirage that shows the value of legitimacy and the fierce competition of values.

Narrative has been considered essential for people to understand and organise their experiences, their memories of what happened, their knowledge, and the succession of time. Things become more understandable, memorable, and closer to the person when they are shared using stories (Bruner, 1991).

STORYTELLING AND SPORT

The use of telling stories in sport and physical education was already suggested by Sparkes (2002) who embraced the potential of tales in the understanding and acceptance of sport and physical activity. This author suggested the use of storytelling as a process of discovery, understanding, and analysis to better disseminate research in the area.

In fact, as stated by Rinehart (2005, p. 507) "Sport is an activity that lends itself readily to the personal experience narrative". This author identified several types of narratives which include the body, culture of pain, disability/ability, coming-of-age, and fictionalized personal modes. Authors such as Smith and Sparkes (2012, p. 80) stated that we "swim in sea of sporting stories and tales that we hear or read or listen to or see". Furthermore, Kretchmar (2017, p. 56) saw important semantic, structural, and cultural similarities between fiction and sport since "sport commonly provides subject matter for fiction".

For a comprehensive review on the use of narrative research in physical education and sport see Pérez et al. (2011) and Devis (2017) who emphasised the need for studies in which the voices and experiences of individuals and groups, their experiences and the implications of the stories for those who share them have to acquire a better understanding of this field.

As per professional sport, Denison (1996) explored the various stages of the retirement process of athletes who had represented their country at the Olympics or world championships. The author presented short stories that reflected his understanding of the sports retirement experiences of these top athletes. In a study on high-performance sport Tsang (2000) wrote about experiences of identity including both academic and athletic voices to show how different stories are told and mirror the ambiguity of identity.

Douglas & Carless (2006) studied the narratives among women professional tournament golfers. They concluded that women use certain narratives to make sense of their experiences in elite sport which include alternatives to the dominant performance narrative existing in professional sport. These narratives are the discovery and the relational narratives which have considerable implications for all those involved. These authors also investigated the use of stories as an effective pedagogical tool in coach education (Douglas & Carless, 2008). Coaches in a development seminar responded by questioning, summarizing, and incorporating the stories provided by the researchers. It was concluded that stories could stimulate reflective practice, increase professional development, and facilitate person-centred approaches with athletes. They provided a practical division of the stories into performance, discovery and relational according to the coaches' views. In this context, Gilbert (2008, p. 51) believed that "the storytelling approach both complements and extends similar approaches in coach education such as coaching scenarios and critical incidents". In fact, the same author stated that "great coaches are indeed great storytellers". He understands that this technique is fully used when helps the learner to reflect and make sense of their own coaching experience. Finally, Douglas and Carless (2015) presented the life stories of real elite athletes along with a careful analysis and interpretation of those stories to better understand the experience of living in sport.

In the case of athletes with spinal cord injury, Perrier et al. (2015) examined how their mentors responded to mentee narratives of sport participation framed with stories of various disabilities. It was concluded that peers and mentors of the athletes were responsive to the mentee's description of the disability and provided a variety of resources and sports information. These stories can support and validate the experiences of these mentees and increase their chances of trying the sport. However, they expressed difficulty in responding to highly defiant narratives, and it was suggested that mentoring training of prospective peer athletes could be designed to help them by practicing methods of communicating with individuals sharing defiant narratives.

In the case of injured athletes, Williams (2020) stressed the relevance of stories and narratives to shape the interpretation of the experience of illness and injury. Athletes can use stories to bring order and provide a sense of identity in a stressful,

disruptive, and confused scenario such as that of an injury. They can use the appropriate narratives to understand health, performance and to frame powerful resources that will assist in their recovery process.

The visual analytics and explanatory storytelling for advanced team sport analysis was explored by Stein et al. (2018) who proposed a method to identify and explain strategies in a team sport. They suggested the classification, specification, explanation, and alteration of match situations by using descriptive storylines. They concluded that their method was useful since it improved understanding and favoured a more effective use of data analysis.

In the context of women sports, authors such as Evans and Pfister (2021) conducted a narrative review on women in sports leadership and concluded that women continued to be under-represented in leadership positions. The authors suggested the need to understand the electoral procedures in place and the experiences of women that step down or were not appointed to different positions. Furthermore, Moyer (2022) have reflected on the narrative of who constitutes a "woman" in sport by analysing the trans-exclusionary narratives in women's sports activism.

In the case of sport management, authors such as Rinehart (2005) argued for the use of a personal narrative and personal storytelling for sport managers to understand how they work affects people and how they interact with others. The use of stories was also explored by Si (2016) to facilitate knowledge using an automated agent which acted as a narrator for the knowledge network applied to the 2008 Summer Olympic Games in Beijing. One relevant aspect is that of crisis management, DiSanza et al. (2018) emphasized the importance of incorporating narrative management techniques into the adaptation phase of crisis communication by assessing reputational threats to determine appropriate responses. They first suggested identifying a crisis type based on several factors that shape stakeholder attributes, and then choosing appropriate response strategies for that type of crisis. They suggested that practitioners could benefit from stories in crisis situations.

Stride et al. (2017) analysed the use of narrative approach in sport management. They used non-fictional stories to present the key findings of a study they did with the Football Association. They concluded that narrative inquiry is an efficient tool for looking into the relationships between societal and sport management issues. In this context, the use of storytelling as a communication tool for creating an organizational culture in a sport organization, which is focused on innovation and change was explored by Gajic (2020). It was concluded that stories can convey knowledge in sport organisations by sharing experiential situations (i.e., case studies, roles playing, etc.), referring to valuable sources, or accessing to valuable images, objects, or situations. Therefore, storytelling used by leaders and organization members can be a tool to generate change in sporting contexts.

As per digital storytelling, Matsiola, et al (2022) analysed the use of digital storytelling in sports narrations with the use of audiovisual tools in a sport journalism course. The authors felt that creating digital stories (i.e., using videos to showcase sports) could help students learning process and facilitate knowledge acquisition. The use of digital tools for creation and presentation of stories was very well received and participants felt that this contributed to the acquisition of skills and the improvement of their educational process.

Sport sciences such as sport and exercise psychology have also analysed the use of storytelling. Smith and Sparkes (2009) stated that sport psychologists can explore the meaning and experience of athletes through the narratives they tell and enact. The stories will help to arise personal and social aspects of the individual lives by showing their complexity and providing an understanding of lives in diverse ways. In this context, personal stories of sport, physical activity, and mental health within a narrative approach to mental health research and physical activity were explored by Carless and Douglas (2010) to rebuild identity through sport and physical activity. Moreover, the way in which sport psychologists communicate with their athletes through storytelling was reviewed by Waumsley (2015) who stressed the importance of using stories with an apparent meaning to the athletes by stating that: "The art of good storytelling is in the process of the delivery not just in the content of the story, much the same in fact, as is the process of building the relationship" (p. 100).

In the area of sports coaching, the application of a narrative approach through stories to articulate and develop the coaching philosophy of the coach has been emphasized. In this context, it has been stated that storytelling is an adequate tool to assist in "clarifying values, articulating a philosophy and aligning actions with values" (Jenkins, 2010, p. 237).

Furthermore, Carless and Douglas (2011) analysed the role of stories as strategies the coaches can use to articulate their personal coaching philosophies because they start with personal embodied experiences which include social and cultural factors and provide an opportunity to recreate significant aspects whose meaning could be explored and reconsidered. They proposed the use of storytelling as a philosophy and as alternative form of reflective exercise by suggesting coaches to identify events clearly remembered and create stories around them that can provide valuable insights.

The use of narrative in coach education and the effect on short-and long-term practice was explored by McMahon (2013) who examined how storytelling can challenge coaches' thinking and doing. This author stated that storytelling offers new ways of seeing the world by allowing us to reflect on our experiences while observing new ways of being. In this study, coaches were presented with stories from athletes to provide alternative perspectives to challenge current and long-term coaching practices. This process provided an important space for coaches to be more aware on what they did or said to their athletes. As a result, a more holistic approach to empathy and coaching was encouraged. It was concluded that athlete stories in narrative form can serve as a powerful tool for challenging coaching practices, thereby developing more socially sensitive practices.

STORYTELLING AND TENNIS

The relationship between storytelling and tennis, although it may not seem like it, goes back to the origins of the game. It is well known that the history of tennis is full of legends about great champions, memorable tournaments, magic events, and unrepeatable matches (Clerici, 1975). Many of these great stories are based on the idea of an admirable feat or achievement. In all of them appear the ideas that are intrinsically associated with our sport: greatness, effort, respect, charisma, grace, style. These are the pillars on which the narrative construction of tennis has been built over the centuries.

For a long time, tennis, more than a sport played in a scenic environment as suggested by Huizinga (2014), has represented a "narrative horizon", magnified by the images of champions and tournaments, which it offered to everyone. Our game has been explored as a literary technique (Carver, 2022) in the sense of how tennis becomes fiction with references, for instance, to David Foster Wallace's Infinite Jest and Vladimir Nabokov's Lolita. Furthermore, the game has been mentioned by authors such as Shakespeare, Chaucer, or Irwin Shaw among others, to name a few examples in the English literature (for a review see Segrave, 2019).

In the next sections, several practical proposals on how storytelling can effectively be used as an adequate tool to market the game are presented. These proposals are focused on both marketing and coaching contexts since they seem to be the ones more likely to benefit from the use of this instrument in the daily operations that may occur in the tennis ecosystem.

By setting different goals and using appealing stories, which are based around meaningful key words that act as a catalyser driving force, facility managers, coaches and others involved can generate the right environments to communicate their vision and ideas.

Tennis leaders both on- and off-court can utilise stories to clearly articulate their own leadership philosophies to support the personal and organisational goals and ambitions for the good of the game.

Storytelling and tennis marketing

Table 1 provides some practical examples on how interested tennis stakeholders can create and maintain a culture where everyone thrives to increase participation at all levels of the game.

Table 1

Practical examples of possible stories that can be used to convey certain marketing goals.

Context	Main goal	Story	Key words
Marketing	Future of the game – Newcomers	"This is the story of the next generation of players. The individual stories of each of them to reach the top, their pathways, their trajectories, the challenges, and opportunities they face. Let's start with player X …"	Generation, youth, energy
	Gender equality – social change	"Tennis is an equal gender sport. It is a sport in which females are recognised at all levels of the game. This is the story of the pioneers of this movement and how they paved the way to where the game is now…"	Inclusion, rights, champions
	Sport for all - participation	"No matter your age, skill level, gender, physical ability, or condition tennis is your game… This is the story of Y, who is 90 years old and plays tennis twice a week. Y started playing…"	More people, more often, more fun
	Health, psychosocial - benefits	"Have you ever wondered how many calories you burn when you play tennis? How does the game improve your reaction speed? In which ways can tennis reinforce your confidence? here are some stories of people that share with us the benefits that they have obtained from the game at various levels …"	Wellbeing, care, life quality

Storytelling and tennis coaching

From a research perspective, Kavanagh (2010) explored the use of narrative by tennis players who became coaches. She tried to understand players' retirement transition experiences, and more specifically, determining what paths lead to successful adjustments. Stories were presented as case studies which showed that the transition from athlete to coach is a complex process that is characterized by having many facets and depend on the idiosyncrasy of the individuals and is best understood on a case- by-case basis.

The narrative of female tennis coaches was studied by Jones et al. (2022). They found that the success of the coaches' career was considered according to the dominant existing narrative which demanded a performance orientation based on a full dedication to coaching. This scenario generated conflict and tension among some coaches who had to face resistance from cultural norms and followed less dominant narratives. It was concluded that career success in tennis coaching is multidimensional concept and alternative narratives should be more available to produce higher levels of female coach attraction, retention, and progression.

From an applied perspective, in the coaching practice, the ability to structure a vision of tennis and its teaching by telling stories can become the key to seduce and motivate players. How can coaches do this? the coach can base each session around a class story. This story inserts certain words or phrases that emphasise the message to be conveyed. It is a matter of defining a script for each lesson.

There are several key ingredients for a good story. The narration should be told with passion, emotion, humour, tenderness, and warmth. The story needs to be congruent and appropriate to the objective. It should start with a phrase that connects the person to the story and catches their attention: "I am sure you have already been in this situation that I am going to share with you…", "Let me tell you something interesting that happened to me a minute ago…", "Here's a story I think you would like to hear…". Table 2 provides some practical examples.

Table 2

Practical examples of possible stories that can be used to convey certain coaching goals.

Context	Main goal	Story	Key words
Coaching	Tactics - consistency	"This is the story of a player that was not enjoying the game because he was taking lots of risks when playing the points. One day he asked his coach…"	Ball in, no mistakes, extra ball
	Technique – grip change	"There was once a player that knew she had to change her serve grip but did not want to because she was afraid of the process…"	Feel it, smooth, loose
	Mental - concentration	"This top player had a challenge in controlling his attention mainly between points. He sought the advice of a sport psychologist…"	Focus, here, now
	Conditioning - speed	"Once there was a player who felt she was quite slow when running to hit the wide balls back. What do you think she did? She…"	Anticipation, positioning, reading

CONCLUSION

The purpose of this article has been to reflect on the importance of using stories in the context of tennis to get a message across that will allow others (i.e., players, coaches, fans, parents, volunteers, administrators, media, members, etc.) to identify themselves with the plot, the characters, or the environment. If the people can take a personal meaning to the story by mirroring the action in it with something they have experienced or they believe in, then it will be easier to motivate them, to "buy" the message and to engage with what it means to them.

This article is also a call to action since it is well known that everyone is capable of telling good stories that will make others think, feel, understand, and act. Storytelling is a powerful tool to change behaviours, motivate individuals, and build relationships through empathy and reflection.

Are your ready to tell your story?

CONFLICT OF INTEREST AND FUNDING

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Physiological and performance effects of high-intensity interval training in tennis players: A systematic review

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ABSTRACT

The purpose of this systematic review was to overview the physiological and performance effects of high-intensity interval training (HIIT) in tennis players. Searches for this review were performed by using four electronic databases: Web of Science, Scopus, SPORTDiscus with Full-Text, and PubMed. Intervention studies investigating the effects of HIIT on tennis players were searched from inception to December 29th, 2021. Seven studies met all inclusion criteria and were included in the study. The findings revealed that tennis players who participated in HIIT interventions had improved their aerobic capacity and tennis performance. Fluctuating results were reported for agility, sprint, and jump performances. In conclusion, the results of the review may suggest that HIIT is beneficial for tennis players to achieve improvement in cardiorespiratory fitness and technical abilities regardless of age, gender, and competitive level.

Key words: Repeated sprint ability; speed endurance training; controlled trial; cardiorespiratory fitness.

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INTRODUCTION

High-intensity interval training (HIIT) is a training protocol that involves short periods of intense exertion followed by brief recovery periods or low-intensity activity (Billat, 2001; Buchheit & Laursen, 2013; Gibala et al., 2012; Gillen & Gibala, 2014; Ross et al., 2016; Bishop et al., 2019). When compared to sedentary (non-exercising) or moderate-intensity groups, HIIT is effective in strengthening cardiorespiratory fitness, aerobic capacity, and body composition (Buchan et al., 2011; Costigan et al., 2015; Kessler et al., 2012; Laursen & Jenkins, 2002; Logan et al., 2014; Sawyer et al., 2020; Sperlich et al., 2011). An increasing body of research shows that HIIT can be an excellent option instead of conventional endurance training, resulting in similar or even better physiological outcomes in healthy individuals compared to a matched-work basis which is still one of the methods of comparisons prevalently used to evaluate the efficacy of HIIT vs. continuous training, as the study by MacInnis et al. (2016) testifies (Hwang et al., 2011; Tjønna et al., 2009; Wisløff et al., 2007). HIIT is recognized as a time-efficient training method based on several physiological, performance-related, and health-related criteria because of its similar or even superior adaptations compared to regular moderate-intensity continuous training (Babraj et al., 2009; Burgomaster et al., 2005; Gibala et al., 2006; Jakeman et al., 2012; Wewege et al., 2017).

Tennis includes high efforts combined with periods of low-intensity activity, with active (between two points) and passive recovery periods (between the games) occurring during a match based on the literature review which often

lasts longer than an hour and, in some cases, more than five hours (Christmass et al., 1998; Fernandez-Fernandez et al., 2009; Kovacs, 2007; Smekal et al., 2001). Competitive tennis players in this situation require a combination of fitness traits such as speed, agility, power, and well-developed aerobic fitness to accomplish high-performance levels (Kovacs, 2007; Ferrauti et al., 2011; Mero et al., 1991). During match play, demands alternate between replacing energy sources and restoring balance in the body during intervals of high-intensity activities such as change of directions, acceleration and decelerations through intramuscular phosphates and glycolysis, and energy requirement for rounds of high-intensity activities through intramuscular phosphates (Glaister, 2005; Smekal et al., 2001; Spencer et al., 2005). As

a result, it appears that professional players' training should concentrate on developing their capacity to complete high-intensity exercises frequently while recovering quickly (Glaister, 2005; Kovacs, 2007). That is why tennis training should incorporate aerobic and anaerobic physical activity.

Tennis requires players to repeatedly generate powerful strokes and rapid movements on the court for a long period of time; therefore, to meet and endure these challenging physiological conditions, modern-day players need a mixture of fitness qualities such as speed, agility, and power combined with well-developed aerobic fitness (Girard et al., 2015; Kovacs, 2007). Thus, developing the capacity to successfully endure high-intensity activities and recover quickly from them, known as repeated-sprint ability or RSA, can provide competitive advantages for players (Girard et al., 2015). To achieve this goal, one option that coaches frequently use is repeated straight-ahead sprint patterns as a streamlined, pre-planned "on-court" or "off-court" high-intensity run on the field (Bishop et al., 2011).

In practice, since young tennis players spend a lot of time on technical and tactical drills, not enough time is dedicated to increasing their aerobic fitness (Crespo & Miley, 1998). To improve aerobic performance, HIIT integrated into game-specific on-court exercises has been advised (Kilit et al., 2018). Such a session aims to preserve technical skills while minimizing training time (Fernandez-Fernandez et al., 2001; Fernandez-Fernandez et al., 2012). However, evidence suggests that while dedicated playing HIIT sessions may meet aerobic goals in cardiac requirements, they might also cause groundstroke velocity- and accuracy-related technical issues in young tennis players (Pialoux et al., 2015).

There are already studies on the effects of HIIT and sports-specific training programs in team sports, mainly soccer (Hill-Haas et al., 2009; Impellizzeri et al., 2006; Sperlich et al., 2011). Yet, to the best of the authors' knowledge, no systematic review has been conducted to investigate the effects of HIIT in tennis. Therefore, the purpose of this study was to overview the physiological and performance influences of HIIT on tennis players.

METHODOLOGY

In the present systematic review, a literature search was performed to maintain the articles focusing on the effects of HIIT in tennis. PRISMA statement (Page et al., 2021) formed the basis of the study and report. Searching procedures are completed for all relevant articles on Dec 29, 2021. Four electronic databases were used. These included the Web of Science Core Collection, which contains a vast collection of literature on science, technology, and social sciences. Another database was Scopus, which is a multidisciplinary database with over 18,000 peer-reviewed periodicals covering a wide range of subjects. SPORTDiscus with Full-Text was another database that provided comprehensive coverage of sports-related literature. The last database was PubMed, which is a database comprising over 35 million citations for biomedical literature from MEDLINE, life science journals, and online books. The Boolean searching strategy was preferred to achieve the full potential of the search engines mentioned above. It was aimed to form a keyword set that covers the articles in sports focusing on tennis. The following keyword structure was set: "tennis" AND ("high-intensity interval training" OR "HIIT" OR "high-intensity intermittent training" OR "interval training" OR "sprint interval training" OR "repeated sprint training" OR "speed endurance training").

Studies were included if (1) they were intervention studies (randomized-controlled or non-randomized-controlled trials); (2) they were conducted with tennis players with no restriction of the duration of the intervention, age, and competition level; (3) HIIT was the focus of the study; (4) they were original articles; (5) they were published in English. Studies were excluded if (1) they were cross-sectional studies; (2) were not conducted with tennis players; (3) used HIIT intervention along with other training methods; (4) were not original articles; (5) were not published in English. Two authors (DD and HO) independently removed duplicates and applied inclusion/exclusion criteria phases. Regarding the criteria application phase outcomes, reviewer disagreements were discussed and solved before finalization.

The Critical Review Form Qualitative Studies (Law et al., 1998) was used to assess the quality of the applied methodology in the included articles. This tool can be used to determine a wide range of qualitative investigations. The following areas were utilized to assess each article: journal level, the aim of the study, background information on the topic, study design, sample group, study outcomes, data analysis methods, findings, conclusion, and implications for future research (Table 1). These questions were scored 1 (meets the criterion) or 0 (does not match the requirements). Total scores for each article out of 15 points were calculated, as 0 point for Not Registered (NR), in which no information was given on the validity and reliability of the instruments employed in the study. The methodological quality of the assessed studies is presented in Table 1. A total score of fewer than seven points indicated low, from seven to ten points indicated good, and eleven points or more indicated high quality (Van der Fels et al., 2015). Two authors independently evaluated the quality of the included studies. Only around 5% of the time, the researchers disagreed about the results. When a discrepancy occurred in the methodological quality of the study, a consensus on the study was reached by reevaluation.

109 studies were attained from the above-mentioned databases (Figure 1). After manually removing duplicate studies (n = 52), 57 studies were obtained for the title and abstract reading. After the title and abstract reading of the studies, 25 full-text articles were evaluated for eligibility. 18 of the 25 articles were excluded as they were not intervention studies (n = 8), were not conducted with tennis players (n = 2), or combined HIIT with other training methods (n = 8). Finally, 7 studies examining the effects of HIIT interventions in tennis were included.

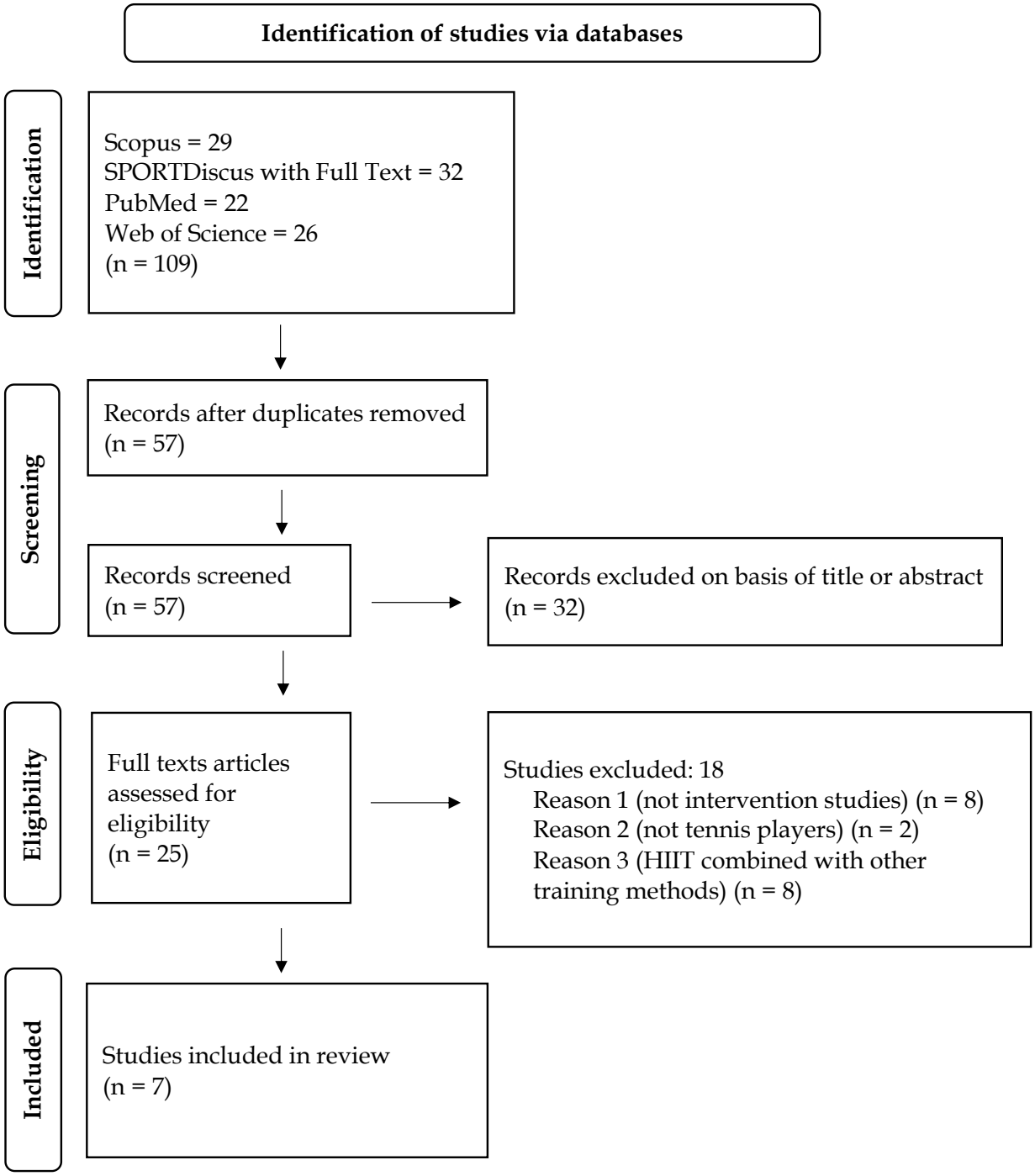

Figure 1. *Flow chart showing identification of studies selected for systematic review*

RESULTS

Table 1 summarizes the overall quality assessments of the studies by using the Critical Review Form - Quantitative Studies (Law et al., 1998). The review included seven studies from the HIIT category. Except for one study (Girard et al., 2015), they were all of high methodological quality. Six studies received 11 to 15 points, with two receiving 15 points (Table 1). The following are the most notable outcomes: Four of the seven studies failed to justify the sample size (item 7), and three failed to report study limitations (item 15). All studies met the criteria and received one point for the first, third, fourth, fifth, eighth, eleventh, and thirteenth items. There was only one study for the ninth item and four for the tenth item. Finally, for the 15th item, four studies met the criteria. Even though six studies had high methodological quality, only two received a total score of 15 on the Critical Review Form - Quantitative Studies. All studies, apart from one (Fernandez et al., 2012), were published after 2015.

Table 1

The methodological quality of the reviewed articles [a].

	Question Number [b]															
Author (Year)*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Brechbuhl et al. (2018)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	14
Brechbuhl et al. (2020)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Fernandez et al. (2012)	1	1	1	1	1	1	1	1	1	NR	1	1	1	1	0	13
Fernandez et al. (2017)	1	1	1	1	1	1	0	1	1	NR	1	1	1	0	0	11
Girard et al. (2015)	1	1	1	1	1	0	0	1	NR	NR	1	0	1	0	1	9
Kilit et al. (2018)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Wiewelhove et al. (2016)	1	1	1	1	1	1	0	1	1	NR	1	1	1	1	0	12

**Only the first author is mentioned; NR = not registered; a 1 = meet criteria; 0 = does not meet criteria; b (1) The study is published in a peer-reviewed journal or book. (2) The study is published in an indexed journal. (3) Was the aim of the study stated clearly? (4) Was relevant background literature reviewed? (5) Was the design appropriate for the research question? (6) Was the sample described in detail? (7) Was the sample size justified? (8) Was informed consent obtained? (9) Were the outcome measures reliable? (10) Were the outcome measures valid? (11) Were results reported in terms of statistical significance? (12) Was practical importance reported? (13) Were conclusions appropriate given the study findings? (14) Are there any implications for future research given the results of the study? (15) Were limitations of the study acknowledged and described by the authors?*

Table 2 provides a review of the included studies and the effects of HIIT programs in the included studies. It contains information about the author, study design, sample, intervention, and results. Three of the seven investigations were controlled, while the other four were not.

Analysis of the studies revealed that three of the seven studies were conducted with competitive-level tennis players (Fernandez et al., 2012; Girard et al., 2015; Wiewelhove, 2016), three with well-trained players (Brechbuhl et al., 2018; Brechbuhl et al., 2020; Fernandez et al., 2017), and one with intermediate players (Kilit et al., 2018). Fernandez et al. (2012) had the most participants of the seven research, with 31 competitive male players. On the other hand, Wiewelhove et al. (2016) had the fewest participants, with only 8 competitive male junior players. Girard et al. (2015) had the youngest participants, with a mean age of 12.8, whereas Brechbuhl et al. (2020) had the oldest individuals, with a mean age of 28.8 ± 5.9. Three studies (Fernandez et al., 2012; Kilit et al., 2018; Wiewelhove, 2016) contained solely male participants, while two studies (Fernandez et al., 2017; Girard et al., 2015) did not state the gender of the final sample.

Brechbuhl et al. (2018) compared repeated sprint trainings (RST) in normobaric hypoxia versus normoxia. This study revealed performance improvements in total time to exhaustion scores ($p < 0.01$, $\eta 2 = 0.01$) in both groups, while aerobic capacity remained unchanged after the intervention. Brechbuhl et al. (2018) reported no significant improvement in repeated sprint ability (RSA) performance following intervention in both groups in their study. They reported that only players who participated in RST in normoxic conditions improved significantly in terms of ball accuracy ($p < 0.01$) and tennis performance index ($p < 0.05$).

In another study, Brechbuhl et al. (2020) compared the short- (the week after intervention) and long-term (3 weeks after Post-1) effects of RST in hypoxia vs. normoxia in competitive tennis players. They revealed performance increases in total time to exhaustion scores ($p < 0.001$) in both hypoxia and normoxia groups, while VO2max remained unchanged after intervention in both groups. Brechbuhl et al. (2020) found significant improvements in the total duration of RSA at Post-1 and Post-2 in the RSH group compared to the pretest. Their results revealed no significant time or interaction effect for heart rate variability.

Fernandez et al. (2012) compared the physiological and performance effects of HIIT and RST in competitive tennis players. Both training methods similarly improved overall aerobic fitness. Their results revealed improvements in VO2peak of 4.9% for RST and 6.0% for HIIT. In contrast, no changes were observed in the control group. Fernandez et al. (2012) reported no increase in jumping or running ability for none of the training methods. Similarly, no differences in 20-m sprint time were reported from the pretest to the posttest. Their findings revealed significant improvements in the RSA mean time. After the intervention, the mean time during the RSA test significantly reduced in the RST; however, no significant differences were reported for the HIIT and control group between the pretest and posttest.

In a similar study conducted with young tennis players, Fernandez et al. (2017) analyzed the influence of HIIT combined with sport-specific drill training (MT) and sport-specific drill training alone (DT) on fitness parameters. Pre- and post-training testing revealed that both groups improved significantly in VO2peak and velocity obtained in the intermittent fitness test (IFT). Fernandez et al. (2017) observed no changes in the remaining variables following the training session. Furthermore, there were no changes between DT and MT after training. Their results showed no significant differences between training groups in terms of the rate of perceived exertion.

Girard et al. (2015) compared repeated maximum unidirectional- and shuttles-sprint trainings in terms of physical tennis performance indicators in 15 competitive teenage players. None of the physical performance indicators in their study showed a major effect of group or any significant interaction between time and group. The Control group had a 3% improvement in performance. However, the unidirectional group outperformed the shuttles group in terms of tennis-specific endurance (Hit & Run Tennis Test). Girard et al. (2015) discovered that both the unidirectional and the shuttles groups significantly improved their isolated (linear 20-m sprint) and repeated-sprint performance, indicating that repeated-sprint training with or without direction change

Table 2

Summary table of studies included for the review.

Study	Participants	Design	HIIT Format	Intervention	Measures	Results
Brechbuhl et al. (2018)	18 well-trained players (16 males and 2 females) between the ages of 18 to 35 years	Non-controlled	Repeated-sprint training in normoxic and hypoxic conditions	12 days, 5 sessions, ~60 minutes	- RSA - TEST - AC - TP	- RSA: remained unchanged after intervention in both groups. - TEST: significantly improved ($p < 0.01$) in both groups. - AC: remained unchanged after intervention in both groups. - TP: ball accuracy ($p < 0.01$) and tennis performance index ($p < 0.05$) improved significantly in only players who participated in repeated sprint training in normoxic condition (RSN).
Brechbuhl et al. (2020)	30 well-trained players (RSH n = 11, RSN n = 11, Control n = 8) 28.8 ± 5.9 years old	Controlled	Repeated-sprint training in normoxic and hypoxic conditions	12 days, 5 sessions, ~60 minutes	- RSA - TEST - HRV - AC	- RSA: Compared to Pre, RSA total time increased significantly at Post-1 and Post-2 (-1.9 and -2.5%, $p < 0.05$) in repeated sprint training in hypoxic condition (RSH) only. - TEST: From Pre to Post-1 and Post-2, RSH improved TEST time to exhaustion (+18.2 and +17.3%; both $p < 0.001$). Markers of TEST performance did not change for both RSN and the control group (CON). -HRV: Did not change in either supine or standing positions. -AC: There was a significant interaction between time and group for total time to exhaustion (TTE) ($p < = 0.05$). Compared to Pre, TTE increased at Post-1 (C18.3%, $p < 0.001$, $d = 0.97$) and Post-2 (C17.3%, $p < 0.001$, $d = 0.97$) in RSH, with no change in RSN and CON.
Fernandez et al. (2012)	31 competitive male players (HIIT n = 11, RST n = 12, CON n = 9) HIIT= 22.6 ± 4.8 years old RST= 21.2 ±5.1 years old CON= 22.1 ±3.3 years old	Controlled	HIIT= 3X (3 X 90 seconds, 90–95% HRmax), with 3-minute rest RST= 3 X (10 X 5-second) shuttle sprints, with 20-second rest between repetitions, 3 minutes between sets	6 weeks, 18 sessions	- RSA - AC - HTT - CMJ - 20-m ST	- RSA: The mean time during the RSA test was significantly reduced in the repeated sprint training (RST) (3.8%; $p = 0.000$) after the intervention, whereas there were no differences between the pretest and posttest for the HIIT ($p = 0.951$) and CON ($p = 0.541$). - AC: Both groups induced similar significant increases in the VO2peak level (HIIT: 6%, $p = 0.008$; RST: 4.9%, $p = 0.010$) whereas no changes occurred in CON. - HTT: Both the RST and HIIT groups showed a significant improvement in their maximum level achieved during the HTT from the pretest to the posttest. The RST group saw an increase of 14.5% (with a significance level of $p = 0.014$) and the HIIT group had a much larger increase of 28.9% (with a significance level of $p = 0.000$). Furthermore, the post-training values for the HIIT group were significantly higher than those of the RST group (with a significance level of $p = 0.010$). On the other hand, the players from the CON group only experienced a small increase of 2.4% (with a non-significant significance level of $p = 0.549$). - CMJ and 20-m ST: The training protocols, HIIT and RST, had no effect on the CMJ performance and 20-meter ST. Additionally, there was no significant change observed in the performance of the CMJ and 20-meter ST for both groups from the pre-test to the post-test.

Fernandez et al. (2017)	20 well-trained players 14.8 ± 0.1 years old DT (drill training) = 10 MT (HIIT combined with sport-specific drill training) = 10	Non-controlled	Mixed high-intensity intermittent runs	8 weeks, 16 sessions, 68.9 ± 12.7 minutes	- AC - 30-15 IFT - AT - CMJ - ST - RPE	- AC: After the training period, there were significant improvements in VO2peak in both drill training alone (DT) and HIIT combined with sport-specific drill training (MT) groups (DT 2.4%, ES = moderate; MT 4.2%, ES = large). - 30-15 IFT: After the training period there were significant improvements in velocity obtained in the intermittent fitness test (IFT) (DT 2.2%, ES = small; MT 6.3%, ES = large) in both groups. - AT – CMJ - ST: After the training period neither of the training programs led to significant improvements in speed/agility (5- to 20-m sprint, 505 test) or explosive power (CMJ). - RPE: No differences were found between training groups regarding the rate of perceived exertion (RPE) (6.4 ± 1.1 vs 7.2 ± 1.3 for DT and MT, respectively).
Girard (2015)	15 competitive teenage players Unidirectional Group: 12.8 ± 1.6 years old Shuttles Group: 13.6 ± 1.5 years old CON: 13.6 ± 1.5 years old	Controlled	Unidirectional repeated sprint training and shuttles repeated sprint training	5 weeks, 10 sessions, ~60 minutes	- HRTT - 20-m ST - AT - RSA - CMJ	- There was no significant difference found in any of the physical performance variables between the groups or any significant change in the variables over time based on the group. - The Unidirectional Group showed twice as much improvement in tennis-specific endurance, as measured by the Hit & Run Tennis Test (HRTT), compared to the Shuttles Group. - The performance improvement in the linear 20-meter sprint, agility, shuttles repeated-sprint ability test, and CMJ tests was 2-3 times greater with the Shuttles Group compared to the Unidirectional Group.
Kilit and Arslan (2018)	29 intermediate level male players 13.8 ± 0.4 years old	Non-controlled	LiHIIT	6 weeks, 16 sessions, Total 203 minutes.	- AC - JT - ST - AT - TP	- AC: Significant changes were observed in VO2max responses in both the HIIT and on-court tennis training (OTT) groups (HIIT: +5.2%, $p < 0.05$, $d = 1.36$; OTT: +5.5%, $p < 0.05$, $d = 1.50$). - JT - ST: Sprinting (20 m with 5- and 10-m splits) and jumping (CMJ, SJ, and DJ) performances improved in both groups from pre-test to post-test ($p < 0.05$, d ranging from 0.40 to 1.10). The 400-m running test time decreased significantly from pre-testing to post-testing in the HIIT (24.9%, $p < 0.05$, $d = 1.32$) and OTT groups (22.2%, $p < 0.05$, $d = 0.60$). - AT: OTT group showed significantly higher performance responses after test than before test (27.0%, $p < 0.05$, $d = 0.88$). - TP: OTT group had significantly higher performance responses in terms of technical scores (+10.7%, $p < 0.05$, $d = 0.77$).
Wiewelhove (2016)	8 competitive male junior players 15.1 ± 1.4 years old	Non-controlled	SiHIIT	14 sessions in 2 four-day periods separated by 4 months	- CMJ - CKA - BLC	- BLC: In both recovery interventions, lactate concentration was significantly increased immediately after training ($p = .001$), and significantly decreased immediately after the recovery intervention ($p = .001$). - CMJ and DOMS: The HIIT microcycle induced a significant decrease in CMJ height and a significant increase in DOMS in both recovery interventions. - PR and Stress: The perceived recovery decreased, and perceived stress increased significantly between testing days in both interventions. - CKA: The Creatine Kinase activity was not significantly different after the microcycle, compared with the baseline values, in the active recovery and passive recovery intervention.

will help players get quicker. Following the shuttles group, performance enhancements for the linear 20-m sprint, agility, shuttles repeated-sprint ability test, and CMJ tests were greater (2-3 fold) than following the unidirectional group.

Kilit et al. (2018) compared HIIT and on-court tennis training (OTT) on young tennis players in terms of psychophysiological and performance responses, and technical ability. They observed significant changes in VO2max responses in both groups. Kilit et al. (2018) found that the OTT group had significantly greater performance outcomes in terms of technical ability.

Wiewelhove (2016) evaluated the effect of repeated use of active recovery on fatigue markers throughout a 4-day shock microcycle with 7 HIIT sessions. They found that the HIIT shock microcycle significantly reduced counter movement jump performance. Wiewelhove (2016) observed that the HIIT shock microcycle led to a significant decrease in perceived recovery, in addition to a moderate to significant increase in creatine kinase levels, delayed-onset muscle soreness, and perceived stress, compared to the scores before the training program.

DISCUSSION

This systematic review investigated the effects of HIIT interventions in tennis players. The main findings of the review are the following: HIIT interventions have significant beneficial effects on cardiorespiratory fitness in tennis regardless of age, gender, and competitive level; structured on-court HIIT exercises are more effective than off-court HIIT training in terms of technical ability; no adverse effect was detected related to HIIT intervention, so it turns out to be a safe and practical alternative to improve tennis performance.

The effects of HIIT related to tennis performance have been attracting the attention of researchers increasingly in recent years because HIIT is a time-efficient training strategy in addition to its undeniable performance effects (Babraj et al., 2009; Burgomaster et al., 2005; Gibala et al., 2006; Jakeman et al., 2012; Wewege et al., 2017). Consistent with the literature, the findings of this review revealed that players in HIIT intervention groups have significant improvements in functional capacities compared to the players in control groups (Brechbuhl et al., 2018; Brechbuhl et al., 2020; Fernandez et al., 2012; Fernandez et al.; Girard et al., 2015; Kilit et al., 2018; Wievelhowe, 2016). To this date, few studies investigated the effects of HIIT interventions on fatigue in tennis players. In their study with competition-level male tennis players, Suárez Rodríguez & del Valle Soto (2017) found that reduced fatigue levels and higher precision in specific tennis-related exercises were achieved. However, in contrast with Suárez Rodríguez & del Valle Soto (2017), Wiewelhove et al. (2016) indicated that HIIT had no effect on exercise-induced fatigue.

The findings of this review showed that HIIT intervention overall has positive effects on physical performances in tennis players. Nevertheless, when specific interval types are observed, this review indicates that tennis players may benefit more from practicing using on-court tennis-specific drills to improve their technical abilities (Fernandez et al., 2017; Kilit et al., 2018). Overall, based on the findings of the review, a HIIT strategy, especially on-court approaches, could be an effective way to develop a more significant physiological demand since an on-court approach has a more crucial effect

on stroke performance than an off-court program; thus, this intervention should be well-integrated into periodization programs of tennis players.

This systematic review may have practical implications for coaches. The findings of the included studies confirmed the effectiveness of HIIT interventions in developing the aerobic capacity of tennis players; therefore, HIIT-integrated exercise programs could help improve players' cardiorespiratory fitness levels. In addition, studies including specific interval programs confirmed the effectiveness of on-court HIIT interventions on players' technical ability and stroke performance; therefore, coaches can benefit from HIIT strategies and programs mentioned in the included studies as tools to give tennis players a competitive edge. This systematic review is subject to one main limitation. Although very general keywords were selected and the exclusion criteria were not too strict, a small number of articles were attained as a result of searching four databases. Therefore, the number of searched databases and languages should be higher to maximize the study's comprehensiveness and reliability.

CONCLUSION

In conclusion, this review aimed to analyze the influence of HIIT interventions in tennis. The main findings of the studies highlighted that tennis players who participated in HIIT interventions had improved their aerobic fitness and technical abilities regardless of age and competitive level which could be considered an effective tool to support players' tennis competitiveness. Another notable result was that structured HIIT exercises positively affected tennis players' technical ability and stroke performance. Since competitive tennis requires too much time to be on the court for technical and tactical skills, this systematic review suggests that structured high-intensity interval exercises could be an effective tool for coaches to improve players' performance by being a time-efficient strategy while meeting the physiological requirements of tennis.

CONFLICT OF INTEREST AND FUNDING

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Theories of skill acquisition: Implications for tennis coaching

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ABSTRACT

This article discusses different theories of skill learning, including ecological dynamics, and their implications for coaching and practice design. Concerns with current beliefs about skill acquisition and the associated traditional practice methods will be discussed. The major tenets of ecological dynamics will be presented, followed by some practice design recommendations for coaches. The goal of this paper is to introduce coaches to a more contemporary theoretical framework of skill acquisition that will drive the exploration of new practice methods to maximize skill development across all ages.

Key words: Skill acquisition, motor skill learning, practice design, practice activities.

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INTRODUCTION

Skill acquisition theory is extremely important for coaches due to its foundational role in the development of skilled performance. However, many coaches either do not acknowledge their beliefs about skill learning, or attach themselves to traditional, sometimes unsupported explanations. The link between beliefs about learning and coaching methods is undeniable, therefore, methods should be grounded in evidence-based theoretical explanations of skill acquisition. The evidence in question, must be driven by academic research findings, and move away from a purely experiential knowledge-based rationale, as often cited by coaches (Reid et al., 2012, Anderson et al., 2021). This does not mean that experiential knowledge is somehow inferior, quite the opposite. It is coaching experiences that often inform research designs which study the efficacy of particular coaching methods. The findings of these studies either support or reject these methods as effective practices, which in turn should inform coaching behaviors. Unfortunately, this is not always the case with many coaching behaviors remaining unchanged even though our understanding of skill acquisition has advanced.

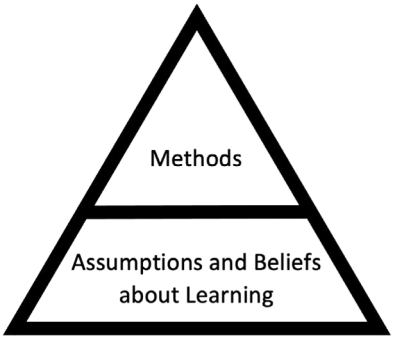

Figure 1. *Relationship between assumptions and beliefs about learning and chosen practice methods.*

Whether we articulate it or not, all coaching methods, practice activities and drills are driven by our underlying beliefs about skill learning (See Figure 1). All coaches believe that the drills chosen for practice "work", but, we must quantify what "work" means. In many instances it should mean the skills transfer to and are effectively applied in game situations.

TRANSFER OF LEARNING

Deciding whether a drill or practice activity "works", must be framed in the context of transfer to the game environment. If skills performed in practice drills do not hold up in games, those drills did not positively influence skill learning. Skill transfer is commonly defined as the influence of previous practice on the performance of the skill in a novel context or performance of a new skill altogether (Coker, 2017; Magill, 2010; Schmidt et al., 2018). This is where a number of drills and practice activities fall short, as they fail to make an effective transition into game performance. Tennis is dynamic and full of complex interactions between players in a variable performance environment, something that repetitive, prescribed drills

do not replicate. Therefore, the question must be asked, does repetitive drilling of the "correct" technique positively transfer to the game? Although many coaches may believe that it does, the contemporary skill acquisition literature would suggest not (Renshaw, Davids et al., 2022; Renshaw, Davids & O'Sullivan, 2022; Pinder et al., 2011; Krause et al., 2018). It is more likely that game-like, representative practice experiences, that are unpredictable and variable in nature, is where transferrable skill learning occurs (Davids et al., 2013).

If this is true, why are repetitive, technical drills so prevalent in practice sessions? It comes down to how we define skilled behavior, as that is what directs our methods and approach to coaching.

DEFINITION OF SKILL

Traditional descriptions of skill include statements such as 'a task that has a specific purpose or goal' and 'the achievement of a high degree of proficiency' (Coker, 2017; Magill & Anderson, 2010). Both of these definitions highlight important elements of skilled behavior – performing in relation to a task goal, and the successful production of a functional movement solution (proficiency). Notice the lack of how the task goal is achieved in these definitions, such as a specific technique. The assumption that 'correct' or 'fundamental' techniques are requirements of skilled performance is presumptuous at best. Plainly put, technique and skill are different (Martens, 2012). So called 'textbook technique' is only one way to achieve a task goal. The technique a player uses, and its potential for success, is highly dependent on individual constraints and the context (game conditions) being faced.

Each individual player can achieve the same, successful movement outcome with their own unique, body-scaled movement solution. The interpretation of proficiency should also be questioned, with many coaches believing it alludes to the repeated reproduction of a specific technique. If the skill "looks good" but does not successfully achieve the task goal, the technique is redundant – the focus must be on task goal achievement. If we look at skill through another lens, proficiency could be defined as the ability to continually adapt to changing task constraints, while achieving the task goal. We could also view proficiency as the ability to effectively perform in different environments, identifying adaptability as a key component of skilled performance. Take court surface for example, grass, clay, and hard courts require skill to be adaptable, suggesting skill is in the relationship between the performer and the performance environment, termed individual-environment mutuality (Araújo & Davids, 2011). Thus, the practice environment should be a very important consideration in the development of skill – ultimately context is key (Otte et al., 2021). Sterile practice environments, such as same ball feed, same court position, same movement solution, has separated the skill from the environment (performance context). Assuming that skills practiced in these sterile environments transfer into a completely different, dynamic performance environment, like a match, is difficult to swallow. Skill is embodied for each individual, meaning it is relative to their organismic constraints and action capabilities, and embedded within a performance environment. The movements performed are shaped by the performance context, it is an integral part of what skill is. Therefore, repetitive technique drills are practicing entirely different skills than those used in competition, as the performance context is vastly different. This means there is not one, correct textbook technique applicable to everyone in every context, and therefore, practitioners should coach accordingly (Gray, 2021).

Practicing a skill repeatedly, in a controlled environment, does not facilitate the development of the adaptable skills required in a match. In matchs, players have to make decisions and act based on information picked up from their opponent and the shot received. They also have to take into consideration game characteristics, such as the current score, which can act as psychological constraint on their decision making and performance. Each person responds to these constraints differently, therefore, the goal of coaching should not be to develop textbook, technical skills, but rather adaptable, functional ones (O'Sullivan et al., 2021). Because a coach's beliefs about skill acquisition drive practice methods, addressing them has to be the main focus if positive changes to practice design are desired.

TRADITIONAL VIEWS OF SKILL ACQUISITION

Two common beliefs about skill learning persist among coaches in all sports, muscle memory and mental representations. Both of these ideas have flaws that should caution coaches from using them as rationale for practice drills and activities.

Muscle Memory

Muscle memory is often used in coaching circles as a rationale for the drills selected for practice, for example "we repeat this technique over and over to ingrain it in muscle memory". The concept of muscle memory is often thought of as an explanation of skill acquisition (it is not) and is generally interpreted in one of two ways:

1. Following significant repeated practice of the correct technique, muscles remember what to do.
2. Following significant repeated practice of the correct technique, skills become automatic and can be performed without conscious processing (Smith, 2018).

Take note of how beliefs about muscle memory is linked to specific coaching methods and practice drills, such as repetitive drilling of technique. Neither of these explanations are supported by the skill acquisition research literature, and therefore, the use of practice drills based on this belief is problematic. Ivancevic et al., (2012) put it quite bluntly in the following excerpt:

> *"from the scientific perspective, the common term "muscle memory", so popular with coaches and players is shear nonsense".*

The truth is, the skill acquisition literature does not even entertain the idea as there is simply no evidence to support it. This does not mean that the term and associated assumptions do not permeate coaching practice, far from it. Roetert et al. (2018) identified the problem with the use and belief in the term in their commentary on Smith's (2018) paper:

> *"The colloquial phrase "muscle memory" is simply inaccurate and could certainly be misunderstood since it promotes the notion that somehow our muscles can store memories which are a brain function".*

If coaches believe that their practice drills develop muscle memory, and that assumption is false, the associated methods, such as repetitive, technical drills, must be questioned.

Mental Representations

A more traditional theoretical approach to skill acquisition is based on the premise that significant practice helps to develop internal, mental representations of movements in the brain that can be recalled in the future. This concept is a key element of schema and motor program theory developed by Schmidt (1975). Although more robust than muscle memory, it still perpetuates a troubling idea, the myth of one correct, repeatable technique (Gray, 2021). If the 'one correct technique' idea is true, every tennis player should perform shots identically. Serena Williams, Rafa Nadal, Naomi Osaka, and Novak Djokovic should all serve, volley, and hit groundstrokes in the exact same way, which they clearly don't. What their performance does demonstrate is that they have each found an optimal way to perform based on their unique organismic constraints and the environmental context they are performing in.

Another weakness of this theory is that is does not clearly consider the important role of the environment, and the information present, in the performance of sport skills. The performer and environment have a shared mutuality, meaning skills are continuously influenced by the environment in which they are performed (Woods, McKeown, O'Sullivan et al., 2020). Performance changes as a function of the playing surface. Grass, clay or hard courts are significantly different due to the player-environment (surface) interaction. For example, players dive for shots significantly more on grass in comparison to hard courts, supporting the idea that skill is in the relationship between the individual and the environment.

In this theory, memories or motor programs are stored in the brain, are retrieved in the moment prior to movement execution. It is unclear why stored representations of movements would be more beneficial than real-time, context-specific information offered by the environment. This theory would suggest that information in the environment, such as movement of opponent or ball flight, is somehow impoverished and therefore must be interpreted and supplemented with these mental representations. More contemporary theories, such as ecological dynamics, would disagree and suggest information embedded in the environment is all we need to act effectively. It is logical to think that interacting directly with, and attuning to, the rich, real-time information in the environment would be preferable for successful action control (Otte et al., 2021). This highlights one of many key differences between traditional and contemporary skill acquisition approaches and has broad ramifications for how we coach and design practice.

Ecological Dynamics: A New Lens

Ecological dynamics is a theoretical approach to skill acquisition combining ideas from ecological psychology, dynamic systems, and complexity sciences (Davids et al., 2013). The theory is grounded in concepts, reviewed below, that fundamentally change how we view skill and its development.

Individual-Environment Mutuality

The performance environment has a direct influence on the individual, it is the mold that shapes how skills are performed. Araujo & Davids (2009) put it best "To do is always to do something, somewhere" emphasizing the functional relationship with the environment that must be realized to be skillful. Skill is not a quantity that we acquire and store as mental representations, it is embedded in the reciprocal, adaptive relationship between the performer and their environment (Araujo & Davids, 2011, Gomez, 2015). This has huge implications for coaching as it suggests the practice context and its representativeness is integral in the development of skilled game performance (Araujo & Davids, 2011; Davids, Araújo et al., 2012; Yearby et al., 2022).

Constraints

A central tenet of this approach is that of constraints and their influence on how we perceive and act in the world. Newell (1986) identified three categories of constraint, labeled organismic, environmental and task, which interact influencing the perception-action cycle, leading to functional movement behavior (see Figure 2).

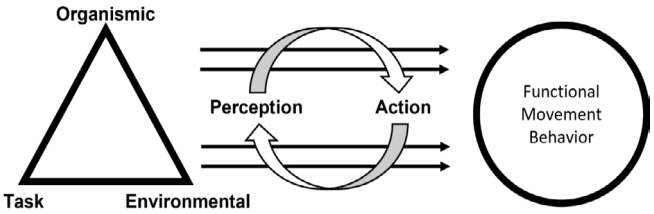

Figure 2. *The Constraints Model (Newell, 1986).*

Organismic constraints are categorized into structural, for example height, strength, flexibility and functional, that are more psychological in nature such as anxiety and confidence. Environmental constraints can be the performance context, for example playing surface, weather conditions, or socio-cultural constraints such as societal perceptions of gender, and socially imposed values. Finally, task constraints are broken down into task goals, rules, and objects, which can be most easily manipulated by coaches in practice. Task goal constraints direct the search for movement solutions as they are ultimately what we are trying to achieve. Instructions are considered task goal constraints as they guide the performer toward certain solutions and away from others (e.g., powerful vs. accurate). Task rule constraints include the dimensions of the court, net height, and game rules, such as serves must bounce in the service box. Task rule constraints can be modified in practice to directly or indirectly encourage the search for individualized, functional movement solutions (Fonseca-Morales & Martinez-Gallego, 2021).

For example, the practice area can be designed to be deep and thin (e.g. rallying on a half court), encouraging long and short shots versus utilizing court width which is no longer afforded. By focusing on achieving the task goal within the rules of the game or practice activity, unique, effective solutions will emerge. This focus on task goal achievement can explain the recent prevalence of underhand serves in top level competition, which are clearly effective. In practice, game conditions (e.g. no bounce zones) and incentivized scoring (e.g. more points for certain actions) are also common task constraints that can guide performance instead of prescribing a specific technique or solution. Finally, task object (and implement) constraints are related to the equipment used, namely racquets and tennis balls. Farrow & Reid (2010) and Buszard et al. (2014) showed that body-scaled racquets and stage-appropriate tennis balls have a positive effect on performance and learning, especially in young players. When taking into consideration the organismic constraints of the

individual and appropriately implementing task constraints to suit, positive behavioral consequences emerge. Fitzpatrick et al. (2018) noted as much, showing stage-scaled courts, racquets and tennis balls resulted in greater rally length, shot variety, and serve success. Buszard et al. (2016) echoed this sentiment, finding full size courts and higher compression balls resulted in fewer hitting opportunities and fewer chances to use a variety of different shots. However, we must be aware that constraint manipulations may facilitate some objectives but possibly not others, it is a fine balance (Reid et al., 2012; Reid & Giblin, 2015). This highlights the importance of constraining to afford by presenting opportunities to solve the movement problem in the activity.

There is always a danger of over-constraining practice tasks leaving only one viable solution - traditional prescriptions of one specific technique is an example. The goal of this approach is not to find the "correct" technique or solution. Instead, each performer is encouraged to search for functional movement solutions that are adaptable to the ever-changing constraints that are imposed. These theoretical ideas have spawned an exciting methodology, the Constraints-Led Approach [CLA] (Renshaw et al., 2010; Renshaw & Chow, 2019), which has been discussed as an excellent approach to develop skilled tennis players (Pill & Hewitt, 2017; Hewitt et al., 2018).

Direct Perception of Affordances

The nature of perception is a common distinction between traditional and more contemporary theories of skill acquisition. Ecological dynamics is grounded in work by J. J. Gibson who proposed that we could directly perceive information from our environment and act upon it without the need for internal mental representations (Gibson, 1979). Directly perceiving environmental information to guide action has significant ramifications for coaching drills and activities. Therefore, the goal as coaches must be focused on helping athletes attune to task relevant information in the environment. In tennis, players perceive opportunities to act, or affordances (Gibson, 1979), such as whether a ball is hittable, returnable or the opponent is passable. These affordances are a function of the player's individual action capabilities. If players do not have the action capability to act effectively, they do not perceive the affordance, despite being a property of the individual-environment system. This is where carefully designed practice activities can be beneficial.

A common occurrence in coaching is when the coach sees an opportunity to act but the player does not. This occurs because they are each perceiving affordances based on their own, embodied action capabilities. A short player may not see approaching the net as an affordance as they could easily get lobbed, whereas a tall player may perceive it very differently. This exemplifies how constraints influence the perception-action cycle, including the presence of affordances, resulting in very different movement behaviors between (See Figure 2). This is also true to for task constraint manipulations in practice, as they will present some affordances but remove others. Helping athletes pick up the potential affordances offered to them will encourage the development of adaptable, functional solutions that are robust when exposed to the changing demands of the game.

As coaches we must be comfortable in the fact that the best source of information to control action does not reside in a player's head (or even worse, the coach's head), but instead within the information-rich performance environment. In tennis, the best sources of information to guide action are the movements of the opponent and the movement of the ball, demonstrating the relationship between how we move and the information we perceive.

Information-Movement Coupling

The relationship between environmental information and our movements is an important consideration for coaches when designing practice activities. As Gibson (1979) put it "*we perceive to move and we move to perceive*", showing that movement changes the information and affordances we perceive, but also perceiving that information changes how we move. From an Ecological Dynamics perspective, it is the information-movement relationship that transfers between a faithfully simulated practice task and a competitive performance environment (Davids et al., 2013; Pinder et al., 2011). Therefore, in sport contexts, the attunement of an athlete's attention to these action-relevant sources of information must be a key component of practice. Practice task design must authentically include this dynamic information-movement relationship to develop skilled performers. This alludes to the need to shift away from repetitive drill-based practice to a more representative game-based approach, encouraging players to find effective, functional movement solutions.

This is just a brief overview of a complex theoretical approach to skill acquisition with a description of a few of its key components. A significant benefit of this approach is that you can see it reflected in movement behavior, meaning the performer-environment and information-movement relationships can be directly observed. It is also important to note that adopting an ecological dynamics rationale to support your practice design does not reduce your coaching toolbox, far from it. A common misconception of this approach and associated methodologies such as the constraints-led approach, is that instructions are prohibited. As mentioned previously, instructions are task constraints and can help guide the search for movement solutions. The issue is with the provision of over-prescriptive instructions emphasizing the repetitive production of a specific technique. In this approach, the role of instruction changes in comparison to more traditional views. You should instruct athletes what to do, meaning the task goal, making them aware of task constraints and incentives, just not how to do it. Players must be provided the opportunity to search, explore and adapt (Chow et al., 2016) to the changing task constraints of the game.

As coaches we have to be confident that with appropriately designed practice activities using constraints, players will self-organize a functional coordination pattern to achieve the task goal (Gray, 2021). By utilizing methods grounded in this approach, such as representative design and task simplification, coaches can design practice tasks that faithfully represent the actions and information sources present in a game. Obviously, a switch toward this approach from a traditional one has important connotations for coaching and practice design.

IMPLICATIONS FOR COACHING AND PRACTICE DESIGN

Adopting an Ecological Dynamics approach dramatically changes the traditional role of the coach, from a provider to a designer and facilitator (Woods, McKeown, Rothwell et al., 2020). The coach helps cultivate a rich performance environment to facilitate growth exemplified by the following quote:

> *"The gardener cannot actually grow tomatoes, squash or beans, she can only foster an environment in which they do so"* (McChrystal et al., 2015).

Non-linear pedagogy, a method aligned with ecological dynamics, outlines five principles for the design of practice tasks: representativeness, constraints manipulation, task simplification, informational constraints, and functional variability, broadly discussed below.

Design Representative Tasks

Practice tasks should authentically represent features of the game. Representative design includes two components, action fidelity, meaning movements from the game are present in practice tasks, and functionality, meaning the information sources used to control those actions are also present. A key outcome of good representative design is the functional coupling between perception and action (Pinder et al, 2011). For tennis practice, ball feed location, speed and spin are important considerations when designing representative practice tasks as the ball and its movement is an excellent source of information (functionality). The presence of an authentic opponent is also important if we are to achieve high levels of representativeness. However, it is important to note that representative design does not mean just playing the full version of the game. Coaches can select slices of the game and then design practice tasks that accurately represent the movements and information sources required for success in competition.

Constrain to Afford

When applying task constraints, we want to avoid over-constraining, pushing them toward one specific solution or technique. Constraints set problems for the player which they must solve in order to be successful. When implementing constraints in practice activities, it is important that they present relevant affordances. Affordances are opportunities or invitations for action offered by the environment or task (Rudd, Pesce et al., 2020). Quality practice design can present, eliminate and/or incentivize particular actions. For example, if the goal is to work on the overhead smash, I can add an incentive constraint to their opponent by offering an extra point for a successful lob, which in turn will present varied opportunities to smash.

Simplify skills, don't break them down

A common, traditional coaching practice is to break skills down into parts, termed task decomposition, the assumption being they can be put back together effectively later. Remember, skills are shaped by the context in which they are performed. Information-movement coupling is where skill exists, therefore this relationship must be preserved in practice tasks. Task simplification, achieves this by modifying games to meet the performance level of the player, including scaled equipment, the dimensions of the playing space, or game rules. The format of the LTA's mini-tennis program is a notable example of task simplification with scaled equipment, smaller courts, and modified game rules to facilitate learning (Fitzpatrick et al., 2018).

Repeat problems not solutions

Bernstein (1967) coined the phrase "repetition without repetition", noting that even in basic, stable movements (e.g. drawing a line back and forth), trial-to-trial variation exists. We simply don't perform an idealized movement pattern each time, emphasizing that skill is in the ability to adapt to changing task constraints (Otte et al., 2021). By introducing variability, players have to attune to better sources of information to guide their action selection. Match-based practice activities, ensure functional variability is present, encouraging players to continually solve the movement problem in front of them. Not only is this more engaging (and fun), it significantly increases the transfer of these skills to the game.

In conclusion, to enhance skill transfer, practice design should mirror the dynamic nature of the game. We simply don't perform the same skill over and over, eloquently described by Nadal:

> *"You might think that after millions and millions of balls I've hit, I'd have the basic shots of tennis show up, that reliably hitting a true, smooth clean shot every time would be a piece of cake. But it isn't. Not just because every day you wake up feeling differently, but because every shot is different; every single one. From the moment the ball is in motion, it comes at you at an infinitesimal number of angles and speeds, with more topspin, or backspin, or flatter or higher. The differences might be minute, microscopic, but so are the variations your body makes – shoulders, elbows, wrists, hips, ankles, knees – in every shot. And there are so many other factors – the weather, the surface, the rival. No ball arrives the same as another; no shot is identical"* (Nadal & Carlin, 2011).

Every shot is different, design practice with that in mind.

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The tennis coach as a leader

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ABSTRACT

Tennis coaches are leaders! Success as a tennis coach involves far more than simply hitting balls over a net daily as the role involves leading diverse stakeholders such as club managers, parents, committees, and most importantly players. The development of leadership skills has received growing interest in recent years, and it is widely accepted that there is a link between leadership skills and corporate success. Sports researchers have recognised the ecological system that surrounds an athlete and the multiple stakeholders connected to their development. However, little is known about how the tennis coach should be educated and prepared to deal with the coach's leadership demands, and the softer skills needed to become a more effective sports leader. The aim of this article is to provide tennis coaches with a brief context surrounding the necessity for leadership skills as a tennis coach. Secondly, the article provides a three-step process based on self-reflection and self-awareness to help coaches consider their individual leadership development.

Key words: Tennis, coaching, leadership, behaviour.

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INTRODUCTION

In the world of tennis, coaching is often viewed as a one-on-one relationship between a coach and a player. However, the reality is that effective coaching extends far beyond the player and involves managing a complex web of stakeholders, including parents, other coaches, sponsors, agents, schoolteachers and many more. In this research article, we discuss the multifaceted nature of tennis coaching and how managing stakeholders is an essential aspect of effective coaching. We will examine the different types of stakeholders involved in the coaching process and their various needs and expectations. Ultimately, our goal is to highlight the importance of stakeholder management in tennis coaching and provide practical guidance for coaches seeking to develop their leadership skills in this critical area. Whether you are a seasoned coach or a new one, this paper will provide valuable insights for coaches on how to manage the many stakeholders such as other coaches (in and outside your program), parents of your athletes and ultimately help players achieve their goals on and off the court.

CONTEXTUAL FACTORS IN TALENT DEVELOPMENT

Talent development (TD) is "a multi-faceted process of optimally nurturing athletes over time within a sport-system" Cobley et al., (2001, p.8) defined. The reference to the "sport system" recognises the significant role of various macro, meso, and micro factors that influence the development of athletes. Researchers have recognised the importance of the environment and contextual influences on overall talent development (e.g., Gledhill et al., 2017; Henriksen et al., 2010). Rather than focusing on methods of developing the individual themselves, Henriksen et al. (2010) proposed a more holistic ecological approach to talent development, shifting the

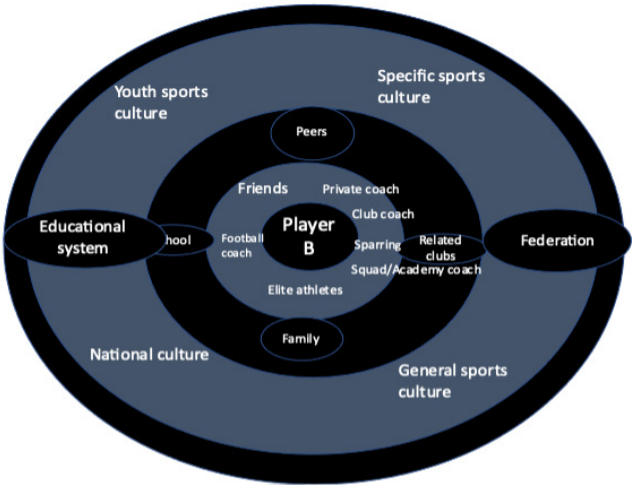

Figure 1. *Sample adapted tennis ecological system (adapted from Henriksen, 2010).*

emphasis from the athlete themselves to the environment in which they develop. This expansion of the literature by Henricksen was centred on seminal work by Bronfenbrenner (1977, p.3), who introduced the ecological environment on child development (non-sport specific). Bronfenbrenner described the ecological system as a set of nested structures, each inside the next, like a set of Russian dolls. At the core of this immediate setting is the developing person, or in a sports context, the athlete. Bronfenbrenner also hypothesised that a person's development is profoundly affected by events occurring in settings where the person is not even present. Indeed, these somewhat invisible macro-level factors contribute significantly to sporting success (e.g. De Bosscher et al., 2006; De Bosscher et al., 2003, Henriksen et al. 2011).

These macro-level influences include environmental factors such as national culture, general sporting culture, and the specific sport (Henriksen et al. 2010). Every context is different; they all have their own unique intrigues that make it highly unlikely that a copy and paste approach can apply in TD (Green & Oakley, 2001; De Bosscher et al., 2006; Bosscher et al., 2007). Therefore, coaches must adapt to these many characteristics and stakeholders.

ROLE OF THE TALENT DEVELOPMENT COACH

Lyle (2002, p.40) described coaching practice as the full range of behaviours, activities, interactions, processes, individual and organisational functions that result from the operationalisation of the coaching role and the coaching process. In tennis, a talent development coach is responsible for identifying and nurturing talented players and guiding them through the various stages of their athletic careers. These coaches typically start off work with individuals and groups of players providing direct intervention to develop their technical, tactical, physical, and mental skills. As players progress through the ranks, coaches must offer intervention support off the court as well as the normal day to day coaching. This intervention support includes roles such as planning sessions, annual planning, and general administration responsibilities. As the player/players develops further the coach must provide constraint management. This involves managing situational factors like support services, schedules, funding and third parties such as sparring partners. Finally, the coach must manage strategic operations such as strategic planning, monitoring, judgment regarding inputs. Therefore, in addition to their technical expertise, TD coaches in tennis must possess strong communication, interpersonal skills and particularly leadership skills.

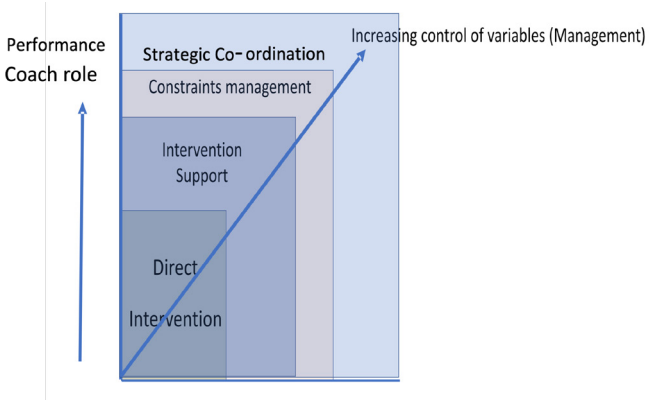

Figure 2. *Progressive role of the TD coach (Lyle, 2002, p.64).*

THE COACH AS A LEADER

There are various definitions of leadership, but one widely accepted definition comes from John C. Maxwell, a leadership expert and author, Maxwell defines leadership as "influence - nothing more, nothing less." This definition is particularly relevant to coaches within TD system where they must influence so many other important stakeholders. Coaches must develop a broader set of skills beyond simply technical expertise. They must be able to communicate effectively with athletes, influence parents, and other stakeholders, manage team dynamics and interpersonal relationships, and provide guidance and support to athletes in both their athletic and personal lives. Overall, the role of coaches in the ecological context of tennis is multifaceted and constantly evolving. Effective coaches must be able to adapt to changing circumstances, contexts, and stakeholders, and provide leadership and mentorship to athletes as they progress and develop.

STYLE OF LEADERSHIPS

It is important to know your leadership style because it can impact the way you lead and influence others. Understanding your leadership style can help you identify your strengths and weaknesses as a leader, which can assist in developing strategies to improve leadership effectiveness. Daniel Goleman, a well-known author, and psychologist proposed six different leadership styles in his article "Leadership That Gets Results" based on his research on emotional intelligence and leadership. Here are the six styles (Goleman, 2017):

Coercive

This style involves demanding immediate compliance and punishing those who do not meet expectations. It can be effective in times of crisis but can also create a negative environment. For example, in tennis this could mean blaming support staff, or players for lack of results.

Authoritative

This style involves setting a clear vision and goals, inspiring and motivating people to achieve those goals. It works well in times of change and uncertainty. For example, if the player is achieving poor results and the coach decides to adapt goals and re-set the program.

Affiliative

This style involves creating a positive work environment and building strong relationships between people. It can be effective in increasing morale and fostering teamwork. For example, in tennis this style may mean creating closer relationships with parents, other key stakeholders and working together towards a goal.

Democratic

This style involves involving people in the decision-making process and seeking their input and feedback. It can lead to more creative solutions and increased engagement. For example, in tennis asking assistant coaches, sparring, science support for input regarding the athlete's plan.

Pacesetting

This style involves setting high expectations for people and leading by example. It can be effective in driving high performance but can also lead to burnout and high turnover rates. For example, in tennis, this could mean setting very high goals for staff and coaches that mean increasing workloads both on and off the court.

Coaching

This style involves developing people through ongoing feedback, mentoring, and coaching. It can be effective in increasing people's skill sets and motivation. For example, in a tennis TD environment, this could involve educating younger coaches, parents and other key stakeholders. Acting as a support rather than dictating the role of support staff.

SO WHICH STYLE SHOULD I USE?

When it comes to leadership styles, certain styles may be more suitable in certain situations depending on the context. The key is to be able to flex your style depending on the context. Here are some examples of the styles within a tennis context.

Scenario 1

Ann is a new coach in my program, she has just qualified but has little on court practical experience. In this scenario I may choose to have a less democratic and more authoritative style in the beginning until the new coach becomes more familiar within the environment. For example, I may show Ann exactly what is needed to warm up the athletes and teach the shots, with the intention of increasing responsibility with time.

Scenario 2

I am sitting on court with my athlete during a match, my player John is a set down seems lethargic and uninterested. Therefore, I am looking for an immediate reaction, so I could use a pacesetting style "come on, we John have higher standards than that, fight", or "John this is not acceptable, I want more than this from you".

Scenario 3

Paul is a pushy parent! He arrives at my office and claims his Johnny is better than all the other players and should be in the best group! The natural tendency can be to lose the cool and end up in a tetchy conversation. However, in this scenario, letting the parent vent and using a more affiliative approach may prove more productive. For example, we both want the best for Johnny, we both have the same goal, we need to work as team etc.

Scenario 4

Judy is a new young coach that has just started in my program, she arrives onto the court looking for his session plan for today's groups. Rather than providing her with the weekly plan, I may decide to use the coaching style. Judy, this week I would you like you to arrange the warmup part of the session, I will act as an observer and at the end of the session I will provide you with feedback".

Scenario 5

I know that I need to raise the standards of our program. At the Friday morning meeting, I explain this to the coaching team. Rather than telling them what I want to do, I take the following approach. Can everyone write down how they feel we can improve? Can you present this back to the group? This Democratic style approach gains greater buy in and is more likely to achieve higher results.

TO BECOME A BETTER SPORT LEADER "KNOW THYSELF".

Leadership books and articles are plentiful and, in many cases, provide useful tips for becoming a better leader mostly within the corporate world. Having a greater understanding of the leadership styles and theory alone will not necessarily help you to become a better leader. Becoming a better leader is a personal journey that requires self-reflection, introspection, and a willingness to make changes. The first step is to understand that Leadership development is not one size fits all and starts with a greater understanding of 'self'. "Know thyself" is an Ancient Greek aphorism that means "know thy measure". According to the Greek writer Pausanias, it was the first of three Delphic maxims inscribed in the courtyard of the Temple of Apollo at Delphi. When it comes to leading players, coaches, parents within a sports system, firstly, it helps to have a greater self-awareness and in particular clarity of personal strengths and weaknesses. Like coaching itself, leadership is an ongoing process in which we are constantly evolving with experience, these three steps provide a useful guide to begin this personal journey.

How do I currently lead?

What are my strengths and weaknesses as a leader? (Reflect on use of styles, skills, and behaviours). This step is useful

Style	Coercive	Authoritative	Affiliative	Democratic	Pacesetting	Coaching
•The leader's modus operandi	•Demands immediate compliance	•Mobilizes people toward a vision	•Creates harmony and builds emotional bonds	•Forges consensus through participation	•Sets high standards for performance	•Develops people for the future
•The style in a phrase	•"Do what I tell you."	•"Come with me."	•"People come first."	•"What do you think"	•"Do as I do, now."	•"Try this."
•Underlying emotional intelligence competencies	•Drive to achieve, initiative, self-control	•Self confidence, empathy, change catalyst	•Empathy, building relationships, communication	•Collaboration, team-leadership, communication	•Conscientiousness, drive to achieve, initiative	•Developing others, empathy, self-awareness
•When the style works best	•In a crisis, to kick start a turnaround, or with problem employees	•When changes require a new vision, or when a clear direction is needed	•To heal rifts in a team or to motivate people during stressful circumstances	•To build buy-in or consensus or get input from valuable employees	•To get quick results from a highly motivated and competent team	•To help an employee improve performance or develop long-term strengths
•Overall impact on climate	•Negative	•Most strongly positive	•Positive	•Positives	•Negative	•Positive

Figure 3. *Leadership styles (Goleman, 2017).*

but only as a steppingstone. Seek feedback: Ask for feedback from your team members, players, and parents. This helps you understand how others perceive your leadership and identify areas for improvement. Consider that some colleagues may not feel comfortable providing honest feedback so using a confidential analysis may be a more useful strategy.

Some useful reflection questions.

Why would someone want to be led by me?

Who do I admire as a leader? What qualities do I like about them?

What are my personal values? Do they align with my leadership style?

Find a trusted mentor or executive coach.

The critical piece is to have a trusted mentor or executive coach to work on during the behavioural change process. Awareness alone will not guarantee change and setting goals, just like we would with our players, is a useful strategy when making changes within our leadership skills. The Prochaska model (Prochaska et al, 2015, pp 98-99) of behavioural change provides an interesting insight into how to go about behavioural change. They identify the steps of behavioural change as pe -contemplation, contemplation, determination, action and maintenance phases of behavioural change. Even though this model is portraited as linear in nature, change is often a process of forward and backwards steps.

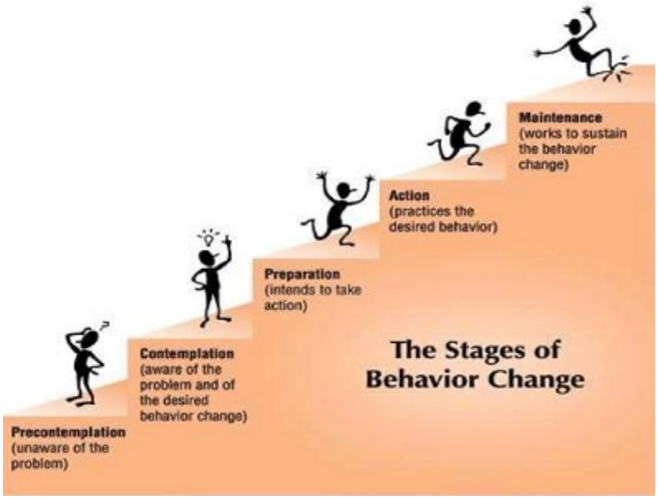

Figure 4. *The stages of behavioural change (Prochaska et al, 2015).*

Regular reflection, re – asses' goals

Regularly reflect and measure the progress on your personal leadership goals. In our busy coaching lives this can be difficult, but it is amazing the difference a few minutes each day can make. Keep a diary to log situations or daily happenings can be extremely useful during conversations with your mentor or coach. For example,

Which styles of leadership did I use today?

If I was in the same situation again, would I do the same thing?

If no, why not?

Finally, after a period of months, compare the thoughts of some people that participated in the original self-evaluation.

CONCLUSION

In conclusion, effective leadership is crucial in any organisation and tennis coaching is no different. The role of a tennis coach evolves with the development of the athlete and as coaches we need to prepare ourselves for this evolution. A good leader can inspire and motivate, while a poor leader can demotivate and demoralise. Leadership is not just about being in charge; there are many styles, it's about empowering others to achieve those goals. Leadership is not a one-size-fits-all, and different situations may require different leadership styles. A great leader knows how to adapt their style to fit the needs of the people around them. Finally, leadership is a continuous learning process. No one is born a great leader, and even the best leaders must constantly work and reflect on developing their skills and knowledge. By seeking feedback, been self-aware, and seeking out new opportunities for growth, leaders can continue to improve and inspire people around them to achieve greatness. Enjoy the journey and remember, the answers to becoming a better sport leader are not on google, they are within!

PRACTICAL APPLICATIONS WITHIN YOUR COACHING PROGRAM

- Have an affiliative approach to working with parents by building strong relationships. Meet the parents on a regular basis to explain what and why you are focusing on within your program. Invite them to attend sessions, explain the rationale behind the type of exercises you are choosing on court.
- Involve your athletes in the decision-making process as much as possible. This Democratic style approach fosters buy in, gains trust and insures alignment of goals.
- Don't just coach the players, coach and mentor each other! Take the time to give and provide constructive feedback to and from the other coaches in your program.
- Regularly communicate with the people off the court! Make a what's app group that includes all key stakeholders that surround your players, for example, parents, physical trainer, sparring partners etc.

CONFLICT OF INTEREST AND FUNDING

The author declares that he does not have any conflict of interest and that he did not receive any funding to conduct the research.

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Can we benefit from motor imagery practice when we have difficulty imagining ourselves?

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ABSTRACT

The objective of this study was to test whether the ability to imagery (i.e., ease or difficulty in creating clear and vivid mental images in one's mind) could influence the speed of service learning in beginner tennis players when they were given motor imagery (MI) practice combined with real practice during their training sessions. The results of this experiment show an improvement in the speed and percentage of success (measured with a tablet equipped with Swingvision software) and in the quality of serves (assessed by expert tennis coaches) of the participants who carried out IM practice before serving. Furthermore, the results show that although players who had difficulty imagining serving performed worse than players who could easily perform MI, after 10 sessions their performance was similar after 20 sessions of practice. Since serving is a complex motor skill, we recommend that coaches use MI, in addition to actual practice, even if players have difficulty generating and using mental images: this will mean increasing the amount of practice.

Key words: Serve, beginner, motor imagery, tennis.

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INTRODUCTION

Tennis is a racquet sport that involves the performance of various complex motor skills, such as hitting forehands, backhands, smashes, volleys, or serves, the learning of which requires a large amount of practice and repetition (Akpinar, Devrilmez, & Kirazci, 2012) and the performance and acquisition of which can be facilitated by the use of motor imagery (MI) as a complement to actual practice (Robin & Dominique, 2022). MI is a conscious process during which the mental representation of a motor action, such as performing a tennis serve, is reactivated in the brain in the absence of actual motor execution (Robin & Blandin, 2021). This mental representation, which can be defined as the internalized model of a motor action and its consequences in the environment (Jeannerod, 1999), is constructed based on sensory information from the environment and the player's body (Dana & Gozalzadeh, 2017). Although it appears that most individuals can create mental images, there are inter-individual differences in MI that are captured under the umbrella term 'imagery ability', which refers to the difficulty or ease of generating and using mental images during imagery practice (Hall, 2001). Research conducted in the laboratory with beginners (Goss et al., 1986) or on the tennis court with expert players (Robin et al., 2007) has shown that participants categorised as "good imagers", using the Movement Imagery Questionnaire (Hall & Pongrac, 1983), had better motor performance than "poor imagers" after IM practice. The results of these studies highlight the need to assess players' imagery skills when considering the use of MI, particularly for tennis progression (Cumming & Ramsey, 2009). Robin and Dominique (2022) have recently shown that MI is a mental technique that is increasingly used by coaches, as a

complement to actual practice, to improve the learning and performance of tennis players, regardless of their level of practice. While some studies have shown beneficial effects

of MI combined with real practice on service performance in beginner players (e.g., Atienza et al., 1998; Dana & Gozalzadeh, 2017), other studies have shown much more mixed effects (Féry & Morizot, 2000; Noel, 1980) which could be explained by an insufficient amount of practice and the failure to consider the participants' imagery capacity.

The aim of this experiment, conducted under ecological conditions, was to test in young beginner tennis players whether the ease or difficulty of doing MI could influence their performance after 20 sessions of practice with or without motor imagery combined with real service execution. We first hypothesized that players who would benefit from motor imagery practice, in addition to real practice, would achieve better serve performance than players who would only perform real serves. Second, we hypothesized that poor imagery participants would need more practice than good imagery players to benefit from the positive effects of motor imagery practice combined with real serve practice.

METHOD

Thirty young beginner tennis players (M = 11.5 years, SD = 1.8 years) volunteered to participate in this experiment which was conducted at the Amicale Tennis Club in Gosier (Guadeloupe, France). The participants (26 boys and 4 girls) were divided into 3 experimental groups: control (N = 10), good imagers (N = 10) and poor imagers (N = 10) according to their scores on the movement imagery questionnaire (MIQ-3f, Robin et al., 2020). This questionnaire differentiates between internal visual imaging, external visual imaging, and proprioceptive imaging abilities. It is composed of 12 items (4 per type of imagery), involving the physical realisation of arm, leg and whole-body movements and then the motor imagery of these same movements. The estimation of the internal visual, external visual and proprioceptive imagery capacities of each item performed and then mentally simulated is done by means of 7-point Likert scales (ranging from 1 "very difficult to imagine or feel" to 7 "very easy to imagine or feel"). A written consent form, outlining the terms of participation in the study, was signed by the parents or guardians of each player. Ethical approval to conduct this research was obtained from the ethics committee of the ACTES laboratory (UPRES EA 3596) of the University of the West Indies (Pointe-à-Pitre, France).

PROCEDURE

During the first session, and before the start of the experimental phases taking place on outdoor tennis courts, participants completed the French version of the movement imagery questionnaire (MIQ-3f). Players who obtained mean scores less than or equal to 2 on the MIQ-3f questionnaire were considered poor imagers and those with scores greater than 5 were categorized as good imagers.

The players then performed 20 tennis sessions in which, after a warm-up that was standardised, they had to perform 20 serves, changing the service box on each attempt. The players in the good and bad imagery groups were instructed, before each serve, to imagine in their minds themselves performing a successful serve (i.e., the ball reaching the correct service box). The players in the control group only made real serves.

During the first session, the players performed the pre-test, which consisted of 10 service balls with alternating service boxes aimed at each trial. The speed of the balls and the percentage of success were measured using a digital tablet (Apple iPad Pro 11 512G) equipped with a performance collection software developed specifically for tennis (Swingvision). In addition, the technical quality of the serves (based on the scores of 6 items: starting position, ball toss, backswing arm-racket movement, forwardswing arm-racket movement, point of contact and end of movement rated with a scale ranging from "0" poor to "7" excellent) was recorded and evaluated by two tennis coaches certified by the French Tennis Federation (for a similar procedure see Robin et al., 2021) After the first 10 practice sessions, all participants performed the intermediate test; then after the 20 practice sessions, all players performed the post-test (10 service balls by changing the service box at each trial) under identical conditions to those of the pre-test.

RESULTS

The results of the statistical analyses (repeated measures Anovas and post-hoc test), showed that all players improved their serving speed between the pre-test and post-test and that the players who benefited from imaging practice, whether they were good imagers (mean = 61 km/h) or poor imagers (mean = 62 km/h), served faster than the participants in the control group (mean = 55 km/h) after the 20 practice sessions as shown in Figure 1.

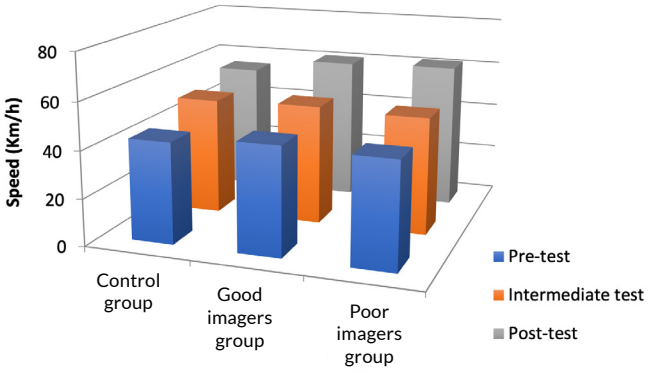

Figure 1. *Service speeds, in kilometres per hour (Km/h), achieved by players in the control, good imager and bad imager groups in the pre-test, intermediate test, and post-test.*

In terms of service success percentage, participants in the good imagery group (mean = 33%) performed better than players in the poor imagery group (mean = 24%) or the control group (mean = 21%) as early as the first 10 practice sessions (i.e., at the intermediate test). In addition, the MI players (mean = 39%) had better service success rates than the control group (mean = 30%) at the post-test (i.e., after 20 practice sessions; see Figure 2).

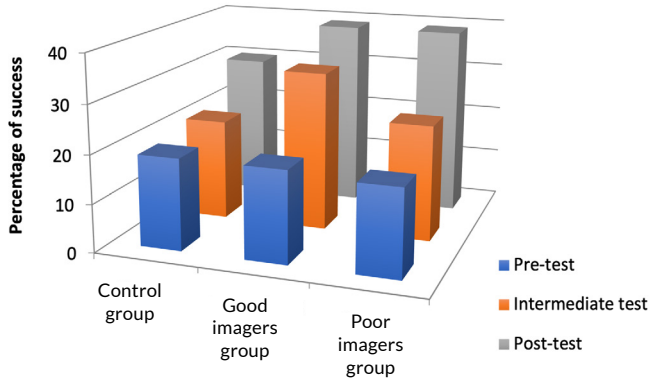

Figure 2. *Percentage of successful services performed by participants in the control, good imager and poor imager groups in the pre-test, intermediate test, and post-test. intermediate test, and post-test.*

Finally, the participants in the good imagery group (mean score = 2.7) obtained better technical scores than the players in the control group (mean score = 2.3) after 10 practice sessions (i.e., intermediate test). Furthermore, the players in the poor imager group improved their technical scores between the intermediate test (mean score = 2.4) and the post-test (mean score = 2.8), i.e., after 20 practice sessions.

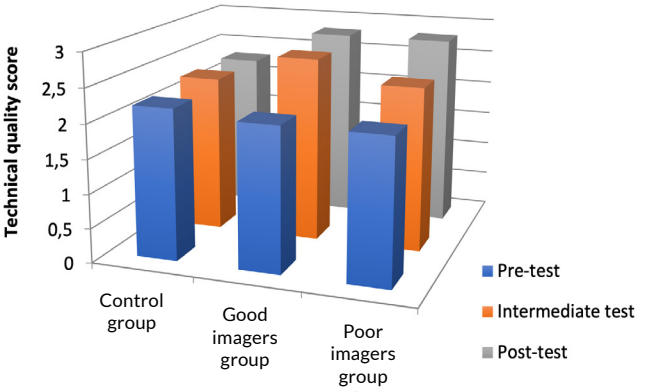

Figure 3. *Technical quality scores of the services performed by players in the control, good imager and bad imager groups in the pre-test, intermediate test, and post-test*

DISCUSSION

This experiment was carried out to measure the effects of motor imagery practice combined with real service practice in young beginner tennis players. On the other hand, the aim of this study was also to evaluate whether the ease or difficulty in creating clear and vivid mental images (i.e., imagery capacity) of a complex motor action, such as serving in tennis, could influence the speed of acquisition of beginner tennis players when they benefited from a combination of motor imagery practice (recall: MI) and real service rehearsals.

The results of this study show, first, that participants who benefited from MI practice in addition to real trials (i.e., players in the good imagery and poor imagery groups) performed better than players in the control group who only physically performed their serves during the 20 practice sessions. These results show the interest of using IM practice combined with the actual execution of motor actions in racquet sports (Cece et al., 2020) and more specifically in tennis (Robin & Dominique, 2022). Moreover, the results of this experiment also confirm the results of previous research studies that have shown a positive effect of MI on performance in novice (e.g., Atienza et al., 1998; Dana & Gozalzadeh, 2017), experienced (Cherappurath et al., 2020; Daw & Burton, 1994; Mamassis, 2005) and expert (Dominique et al., 2021; Robin et al., 2007) tennis players. As discussed by Hardy and Callow (1999), it is possible that practice in MI allowed players who benefited from this mental technique (i.e., the good imagery and bad imagery groups) prior to serving to visualise the overall movement of the serve as well as the different positions and steps required to perform this motor skill more easily. Furthermore, it is also possible that the players in the good imagery and bad imagery groups benefited from the motivational function of MI (Robin & Dominique, 2022): the combination of this mental practice and the physical practice of the serves being more motivating to perform than the simple real executions done by the players in the control group.

Secondly, the results of this experiment show that the players who had difficulties in generating and using mental images (i.e., the participants in the poor imagery group) needed a greater amount of practice than the players in the good imagery group to become as good as them. Indeed, while the latter obtained improvements in service performance within the first 10 practice sessions, it took twice as many practice sessions for the poor imagery group to become equivalent to the good imagery group. These results confirm work in the literature showing differences in acquisition speed for simple movements (Goss et al., 1986) or in performance in complex motor skills (e.g., return of serve in expert tennis players; Robin et al., 2007) as a function of participants' imaging ability. This modulation of acquisition speed between participants in the good imagery and poor imagery groups could be explained by the fact that a good IM capacity would facilitate the construction of the mental representation of the action to be performed (i.e., serve) and the encoding of information in long-term memory (Robin & Dominique, 2022) solicited during the mental simulation of the serves.

To facilitate the creation of mental representations of the actions to be imagined, particularly for beginners and/or those who have difficulty imagining the movements, Guillot et al. (2005) showed the interest of carrying out the MI in costume, on the court, with the racket in the hand. Other authors have shown the positive effects of using internal discourse, particularly on the steps involved in the execution of a service (Robin et al., 2021), or of watching videos before performing the MI (Atienza et al., 1998; de Sousa Fortes, 2019) for novice tennis players. It would be interesting to evaluate, in future research, whether these strategies would be beneficial, specifically for players with difficulties in performing MI (i.e., poor imagers), to facilitate the learning of complex motor skills such as the tennis serve.

CONCLUSION

The results of this field study confirm research that has shown that motor imagery, when used in conjunction with actual practice, can improve serving performance in beginning tennis players. Although participants categorised as poor imagers using an imagery questionnaire performed worse than players in the good imagery group after 10 practice sessions, their performance became equivalent after 20 practice sessions. We therefore recommend that coaches and trainers use MI, in addition to real practice, even if the players have difficulties in generating and using mental images on the field, by adapting the number of practice sessions according to the participants' imaging ability.

CONFLICT OF INTEREST AND FUNDING

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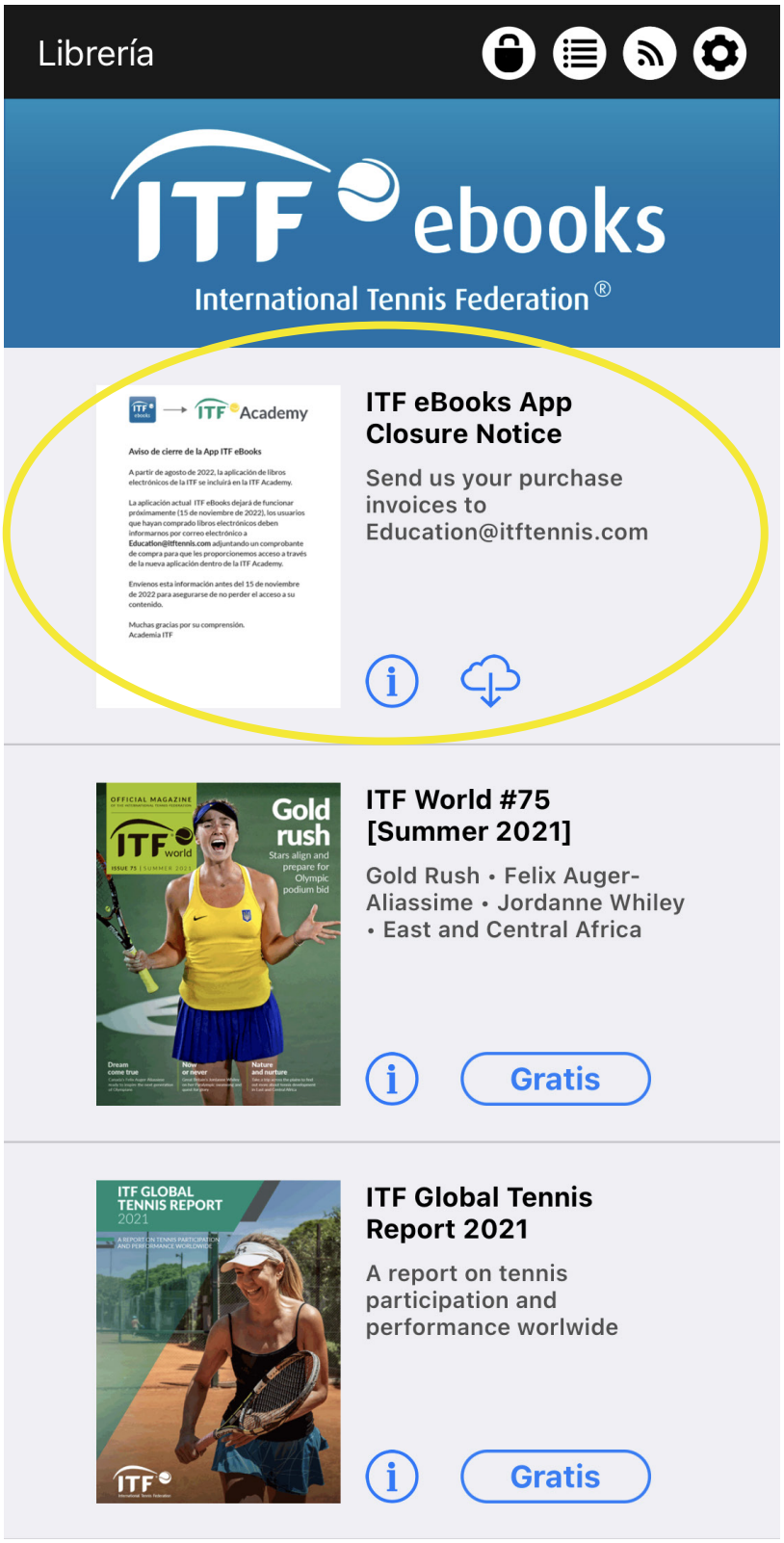

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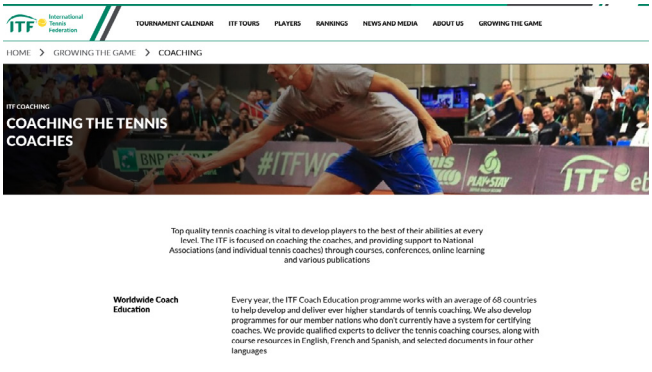

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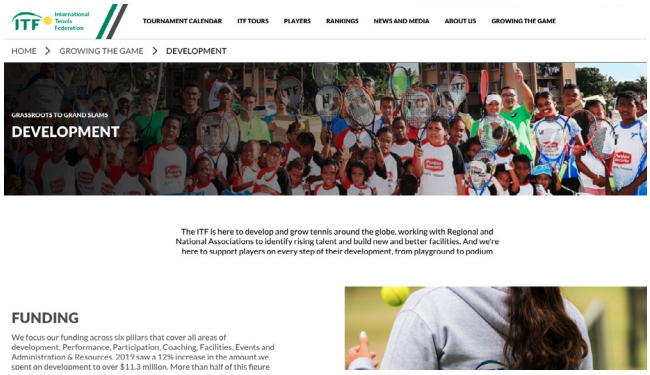

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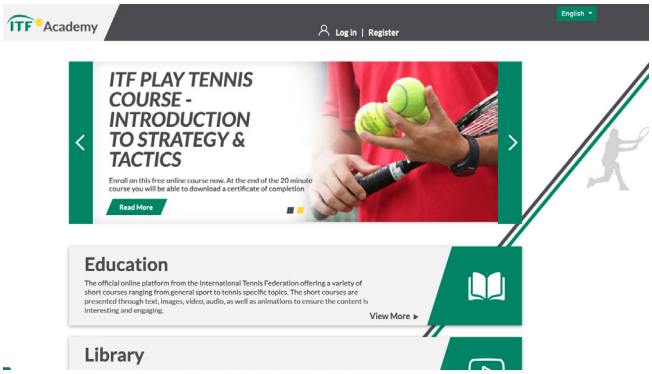

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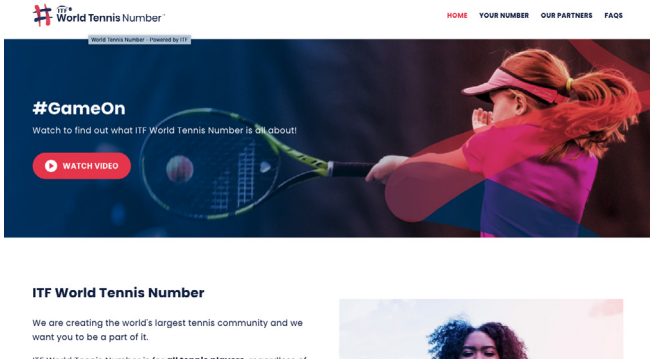

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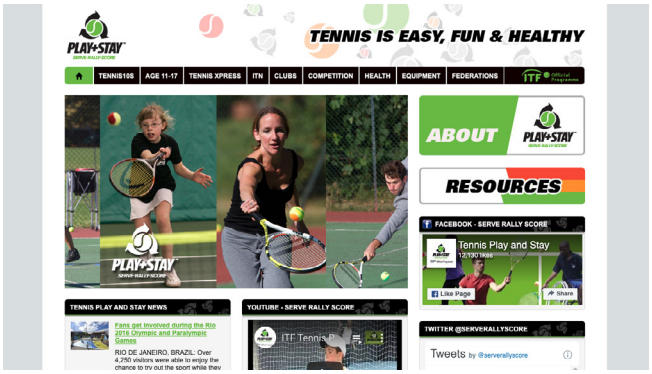

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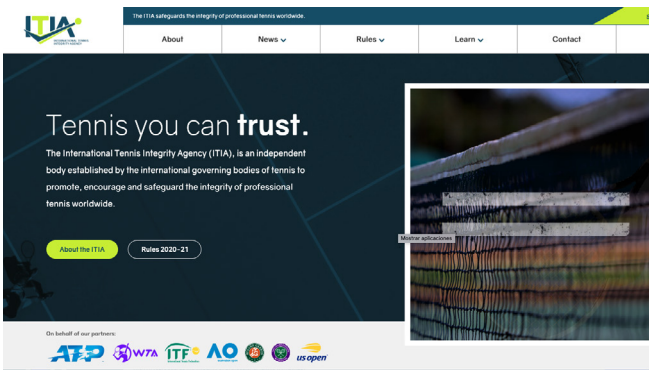

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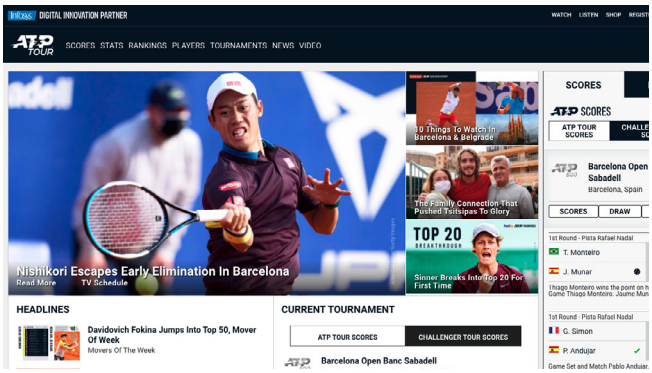

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