International Tennis Federation

COACHING & SPORT SCIENCE REVIEW

www.itfcoachingreview.com. April 2021. 29th Year. Issue 83. ISSN 2225-4757

Issue 83

COACHING & SPORT SCIENCE REVIEW

www.itfcoachingreview.com. April 2021. 29th Year. Issue 83. ISSN 2225-4757

Editorial

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Welcome to issue 83 of the ITF Coaching and Sport Science Review. This issue is the first one of 2021 and it marks an important achievement for our journal. We have launched a new page that includes the articles in individual files as well as a new digital submission system that will improve the quality and visibility of our publication. The new page can be accessed here.

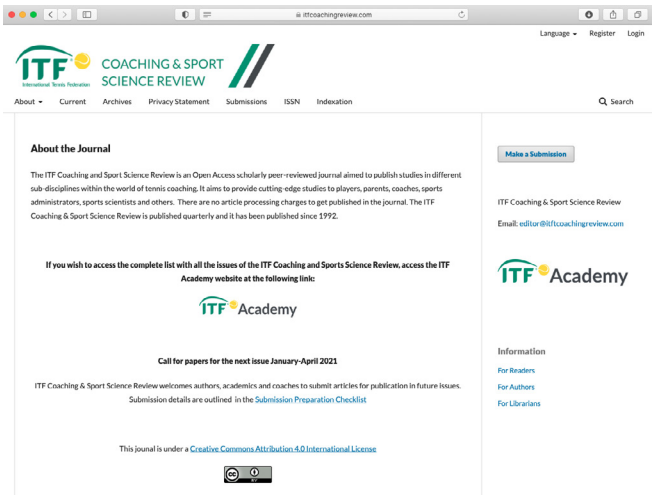
This issue includes contributions from all over the world and cover a wide range of topics such as match fixing, performance factors in wheelchair tennis, marketing and communications, injuries in female players, acceleration training, kinematics of the serve, variability in the warm-up, innovation in tennis, etc.

The coronavirus pandemic has confronted the entire world with unprecedented challenges. We would like to thank all the tennis stakeholders very much for your continued commitment to develop our sport, overcoming the many challenges and supporting the safe and successful delivery of the training programmes, competitions and events that have helped to keep the tennis activity running in these times. It is very reassuring and helpful that many tennis organisations have successfully held programmes and events which are safe and secure.

The ITF Development Department continues to work towards the ITF's goal of increasing participation worldwide from 87m to 120m players by 2030: "30 by 30". The ITF Global Tennis Report will be published in July 2021. The global data provided by member nations in this report will continue to inform the ITF development strategy .

The ITF Academy, the official educational platform of the ITF has more than 34,000 registered users and 135,000 anonymous users with access to more than 135 English courses, 110 French and Spanish courses, 75 courses in Portuguese and 80 courses in Russian. The Players section of the ITF Academy has 16 courses, and more courses will be uploaded in due course. Please click here to register for free now.

The ITF Advantage All: Gender Equality strategy is gaining momentum. The Leadership development programme was launched in March and a high-level Advantage All Global Forum was held on April 12th as a virtual event with high profile speakers and an impactful content agenda to address the barriers and discuss solutions for equal opportunity in tennis.



The ITF has announced that more than 100 nations from across six continents have signed up to launch the ITF World Tennis Number from 2021. Together, these countries account for 68 million tennis players, equating to 78% of the world's playing population. The ITF World Tennis Number will establish a single global tennis rating for players of all ages, genders and abilities, making it easier than ever for people to find opponents that are evenly matched to them, wherever they are in the world. Featuring a host of innovative features, it is powered by a state-of-the-art algorithm that analyses performance data and millions of match results in order to provide players with a real-time skill level rating that will enable them to have more meaningful and enjoyable tennis experiences. Please click here to access to more information.

The 2021 ITF World Participation Conference (WPC) will be hosted virtually from 12-14 July. The Conference will continue to provide an interactive forum centred around shared practices and discussions with keynote speakers from within the tennis family, other international sports and leading experts from the specific Conference topics. Details will be communicated in due course.

The ITF continues to support the 139 active National Associations that are involved in the ITF Junior Tennis Initiative (JTI). The programme had 10 new nations becoming active during 2020. Since the pandemic hit, the ITF Development Officers have organised over 30 specific virtual conference calls with their respective region's National JTI Coordinators.

During 2021, a Rule of Tennis trial will be conducted under Appendix VII "10-and-under competition". The amendment was submitted to the Rules of Tennis Committee in December 2020 following an in-depth research study conducted for the ITF by Tennis Australia and Victoria University, Melbourne. The height of the nets used for 10-and-under competition were reviewed and the recommendations were to amend the previously stated heights. The aim of the rule change amendment is to allow more young players to experience greater success when playing on the designated "red", "orange" and "green" courts.

We would also like to encourage new submissions to the ITF CSSR using the new system that can be found in the journal web page. Finally, we would like to thank all the authors for their contributions, as well as all of those who sent in proposals. We hope that you enjoy reading the 83rd edition of the ITF Coaching and Sport Science Review.

COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 4-6.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.45

Match-fixing threats: Effective responses of coaches

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ABSTRACT

Incidences of match-fixing impinge on the integrity of the game and undermine critical confidence required to grow the sport. This paper reviews match-fixing in light of recent media coverage and highlights the role coaches can play to strengthen the core values of true competition, fair play and sportsmanship. Several strategies for coaches to consider are proposed.

Key words: match-fixing, integrity, Tennis Integrity Unit

Received: 20 January 2021

Acepted: 25 February 2021

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INTRODUCTION

It was front-page news in a leading newspaper, Two Charged over Alleged Tennis Match-fix Syndicate (Vedelago, 2020, p.1). The match-fixing story reported Victorian Police had charged two alleged members of the Australia wing of an international tennis match-fixing syndicate. It was alleged the syndicate had recruited low-ranked players from Europe and South America to throw matches while associates placed bets with bookies on the other side of the world.

The story's prominence on the front page was surprising given the havoc being experienced at the time by COVID-19. Sharing front-page billing with an update on the infection count from the virus demonstrated the gravity of the match-fixing story. It was a story that went to the heart of integrity in tennis, in a renowned and proud sporting nation, Australia.

Granted the majority of tennis events are on hold internationally at the time of writing this paper due to COVID-19, the interest in the integrity of tennis is however not on hold. Nor is the need to examine the threats to integrity on hold. Accordingly, it is arguably a good time to extend Valino's (2019) paper on match-fixing in tennis and highlight the role coaches can play to strengthen the fight against this serious threat to the game's integrity. Let's first put match-fixing in context and review what we mean by integrity in tennis.

INTEGRITY IN TENNIS

Integrity in tennis is the manifestation of the ethics and values which promote community confidence in the game, including:

- Fair and honest performances and outcomes, unaffected by illegitimate enhancements or external interests.
- Positive conduct by players, administrators, officials, coaches, supporters and other stakeholders, on and off the court, which enhances the reputation and standing of competition and tennis overall (Australian Government Department of Health, 2016).

This definition highlights that the presence of integrity is a cornerstone for community confidence in the game. Integrity underpins participation rates and has a direct impact on reputations, commercial revenue and sponsorships for individuals and tennis entities including clubs, teams and associations (Wood, 2016).

In terms of threats to integrity in tennis, these are not limited to match-fixing. Threats also include doping, harassment, bullying and discrimination; child protection; health and safety issues; regulation and supply of performance and image enhancing drugs; selection disputes including those stemming from possible gender issues and governance issues. As evident in the newspaper report cited above, match-fixing and doping tend to attract more media attention than other forms of threats to the game (Wood, 2016).

MATCH-FIXING

Match-fixing (also known as 'competition manipulation' or 'cheating to lose') involves the manipulation of an outcome or contingency by players, teams, coaches, officials and others. It can include:

- The deliberate fixing of the result of a match, or of an occurrence within the match or of a points spread
- Deliberate underperformance
- Withdrawal (tanking)
- Deliberate misapplication of the rules of competition
- Interference with the play or playing surfaces
- Abuse of insider information to support a bet placed by any of the above or placed by a gambler who has recruited such people to manipulate the outcome or contingency (Department of Health, Australian Government, 2014)

Generally, there are two key motives driving match-fixing:

- Wagering-related corruption to secure a pecuniary benefit
- Non-wagering-related manipulation, which might involve accessing prize money or qualifying points; ranking and draw manipulation; official bias and favouritism or other motivations (Wood, 2016).

Within these categories there are different types of 'fixing'. The two dominant ones are:

- Manipulating the overall outcome of a match
- Manipulating an 'event' within a match (also known as a 'spot-fix'), for example winner of the first set (Wood, 2016).

It is noted that spot-fixing compared with match-fixing is easier to execute, more difficult to detect and likely to generate a lower profit on wagering markets. Notwithstanding, the rapidly growing global wagering markets pose a significant risk to an increase in both spot-fixing and match-fixing. A wager can now be placed from virtually any location in the world and there are sophisticated criminal syndicates that make detection onerous. Alarmingly, tennis has been identified as a high-risk sport for match-fixing given it attracts significant and highly liquid betting markets (Wood, 2016).

It is recognised that some coaches, officials and players are vulnerable to engaging in match-fixing due to personal weaknesses and compromise, financial and other pressures or ambitions. These vulnerabilities can be exploited by criminals or others, through blackmail, extortion or grooming (IOC-INTERPOL, 2016). With respect to players, the most vulnerable are those competing in the lower-tier professional ranks where prizemoney rarely covers a player's expenses of travel, accommodation and coaching (Valino, 2019). The strongest match-fixing risk factors for coaches and other officials are negligible pay and a lack of financial security (Bricknell, 2015).

To date there are no known sanctions or prosecutions against tennis coaches for complicity in match-fixing (other than an Australian coach who committed the offence when he was a player ["Qld tennis coach avoids jail for match-fix", 2018]). This is an enviable achievement and one that can be maintained, and indeed enhanced, when coaches lead by example with a proactive response to match-fixing threats. The sphere of influence from such conduct by coaches can be extensive given they are well positioned to influence players, support persons and others in the tennis community. How might coaches take a leading role to stamp out match-fixing? Let's review some of the strategies coaches might consider.

RESPONSES TO MATCH-FIXING THREATS BY COACHES

Coaches might consider adopting some, or all, of the following strategies depending on individual circumstances. The list of strategies is not exhaustive but rather highlights a selection for consideration.

Keep abreast of match-fixing developments

The Tennis Integrity Unit (TIU) website (https://www.tennisintegrityunit.com/) is an excellent source of resources, news and inter-active material. The website also provides links to ITF Knowledge (https://education.itftennis.com/#/entry) and ITF Academy (https://www.itf-academy.com/) where additional content and on-line courses are available. Regular review of these websites can help ensure coaches have the latest knowledge about match-fixing (e.g., the methods used by criminal gangs to attempt to corrupt or comprise coaches; reporting obligations; support and counselling services; code of conduct and rules regarding betting).

Do a financial health-check

Avoiding financial difficulties can significantly minimise the risk for coaches to be targeted by betting syndicates associated with match-fixing (Wood, 2016). It is sound practice to seek financial planning advice to avoid running up unmanageable debts. Discussing financial concerns with one's employer or a support person can also help to minimise vulnerability to match-fixing syndicates due to stressful financial circumstances.

Play a safe game of zero betting

Not betting on matches and not instructing, encouraging or facilitating others to place bets are 'fail-proof' strategies. Absenteeism from betting on matches (or aiding others to place bets) substantially minimises the risk of any possible perception or allegation that a coach may have received a dubious, unethical or illegal payment, gift or other benefit from an involvement in match-fixing. Adopting a 'zero betting' approach ensures there is no basis to, or evidence of, wrong-doing by a coach.

Protect 'inside' information

Coaches need to guard sensitive and confidential information (e.g., injuries to players, the form of players) that would allow others to secure an unfair advantage or financial gain from betting on a match. It is to be expected that coaches have 'inside' information about players but what they do with such information is critical. Being mindful of what coaches communicate with others is essential. It is also prudent for coaches to be mindful of the possibility communications with others may be overheard or accessed (e.g., emails left open on a computer for others to see; comments posted on social media) and subsequently misused by 'third-parties' (Young, 2012). Coaches need to be vigilant and avoid such situations when information needs to be protected.

Do not hesitate to report

The Tennis Integrity Unit (https://www.tennisintegrityunit.com/) was established to investigate integrity concerns so coaches should not hesitate to report if they hear something suspicious or if approached to fix any part of a match. Coaches can take comfort knowing it is not their responsibility to

investigate matters but it is their responsibility to tell the relevant authority (it could also be an integrity unit at a coach's national association if such a unit exists) [ITF Code of Ethics, 2019]. Coaches may well find it a considerable relief to share their concerns with the Tennis Integrity Unit. Doing the right thing (by reporting concerns) can greatly enhance a coach's well-being and sense of self-worth (Young, 2009).

Instil in players a 'best efforts' mentality

A guiding philosophy for coaches is to encourage players to always give their best in matches, playing each point with 100% effort. Adopting this approach, both coach and player are unlikely to even entertain the idea a player would deliberately underperform or 'tank' a match. As a team, a coach and player put a protective ring around themselves from match-fixing threats because the goal is always for the player to give his/her best efforts in an ongoing pursuit of developing the player's full potential. Coaches can instil in players it is all about learning from matches, identifying areas for improvement and giving one's best endeavours both on and off the court over an extended period. There should be no shortcuts or diversions from the 'best efforts' mentality!

Implement education sessions and discussions with players

Coaches can conduct information sessions, and initiate fruitful discussions, about match-fixing threats with players. For example, it can be most beneficial if players understand the methods criminal groups may employ in their attempts to corrupt, compromise or blackmail players into match-fixing. It is also critical for players to understand the serious repercussions and penalties if found guilty of involvement in match-fixing. Sharing case studies of convictions (https://www.tennisintegrityunit.com/investigations-and-sanctions) with players can be a powerful means to illustrate how any perceived gain or benefit from match-fixing is completely eclipsed by the risk of bans, fines and reputational damage. Key information for coaches to impart to players can be sourced from the Tennis Integrity Unit, the International Tennis Federation and/or national tennis and coaching associations.

CONCLUSIONS

Match-fixing, whether it is related to betting or not, is a curse on the game. It rocks the foundation of confidence in the game's integrity. We all want to enjoy and engage in tennis knowing the game is played honestly, fairly and with good sportsmanship. Regrettably across all levels of the game, financial gains and other benefits can entice individuals to attempt to influence the results of matches (Wood, 2016). The containment of the growing global threat of match-fixing is, to a large extent, entrusted to the Tennis Integrity Unit. However, coaches can also play a key role to strengthen the core values and rules of the game that ostracize and penalise those found to engage in match-fixing. What is of critical importance to a coach is his/her professional reputation. Taking a proactive stance against match-fixing can only enhance that reputation. It also has the advantage of positively influencing players and others in tennis given the status of coaches as mentors, role models and leaders in our sport. Match-fixing can be beaten with the help of coaches and the tennis community. To do so will have direct consequences for the many health, social, economic and cultural benefits that tennis generates when it is clean, fair, safe and inclusive.

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COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 7-9.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.46

Integrated marketing communications in tennis

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ABSTRACT

The objective of this article is to serve as a support for the many tennis stakeholders interested in promoting their services or strengthening their brands through a combination of marketing and communication strategies, with special emphasis on digital tools. This will allow them to achieve their goals more efficiently and at a lower cost.

Key words: marketing, public relations, communications, promotion, brand

Received: 9 January 2021

Acepted: 19 February 2021

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INTRODUCTION

The advancement of technology in the last 20 years has changed the way we carry out our daily tasks, thus it has also permeated different areas of knowledge, with communications having the highest impact (Gruber, 2014).

This reality, with the Internet as the main ally, has driven blogs, websites, social media, Wi-Fi, and others that did not exist two decades ago or were just in the making. Each of these elements (Estrella and Segovia, 2016) are currently used, both in public relations and in marketing. These two areas sometimes bifurcate and in others come together with their own methods promoting a product or institution to the target audience.

To avoid conceptual discussions, whether public relations belongs to marketing or vice versa, I want to focus on the modality of Integrated Marketing Communications (IMC), which, as the name indicates, integrates marketing and public relations or communications to transmit its messages with the implicit intention of winning clients or consolidating the brand, depending on the place from where it is applied.

In tennis, for example, a federation/association can use the IMC to attract more players or to improve her image through the promotion of programs and services, without the need for profit. However, in a tennis club or academy, by using the same methods, the aim may be to attract more and better players, which could translate into a direct increase in customers and indirect in business, which is the same as saying sales.

Several investigations have addressed this topic in tennis. Bennett et al. (2006) studied the application of this methodology in the measurement of marketing communications during a professional tennis tournament. In another work, Kim et al. (2009) studied innovation and strategic improvement through marketing, communication and the study of the tennis racket market. Schoenstedt and Reau (2013) investigated the use of social marketing

in professional tournaments, Tufekci (2013) analyzed the role of the brand on the audience of a women's professional tournament and Smolianov et al. (2014) compared USTA practices for increasing tennis participation with those of an integrated marketing and communication model. For their part, Chmait et al. (2020) analyzed the "influencers" in tennis and their role in social networks when it came to increasing public attendance at a professional tournament.

The versatility of the IMC is as wide as tennis itself is, since not only clubs and federations can benefit from it, but also players who can use it to create or strengthen their brand and tournament owners to promote their activities and identity and even the International Tennis Federation can also add more value to the ITF brand and attract more resources to further develop tennis in the world.

FROM THE BEGINNING

When executing successful marketing and communication strategies, the main thing is to know what audience we are targeting (preferences, demographics, socio-economic variables, etc.), what will be the approach and by what channels. This is before determining the realistic and

measurable objectives adjusted to a specific time so that once the application of the strategy is concluded, its success can be measured (Báez, 2000).

When executing successful marketing and communication strategies, the main thing is to know:

- What audience we are targeting (preferences, demographics, socio-economic variables, etc.);
- What will be the approach;
- By what channels to go through.

The 2019 ITF Global Tennis Report noticed that 87 million people play tennis in the world. This is based on the number of players and possibly does not include the tennis followers in junior, senior or professional tennis. Same for Grand Slam only followers. The target audience most certainly needs the significant others (Family and Friends) also.

Another vital aspect is the available budget to get the most out of the project. This is, in practical terms measured by the size of the target audience we have to reach for each dollar invested.

For example, a billboard on the busiest avenue in any city would cost thousands of dollars because it can be seen by hundreds of thousands of people, but how many of those people are part of our target? It is difficult to measure. On the other hand, in social media, search engines or websites and the advertisement of a campaign are only seen by the people who have considered the target.

There are several methods to know the audience to which we are directed and the media to which they are linked. To do this it is necessary to carry out a psychographic analysis. This is in addition to demographic data, to know their preferences, their lifestyle, their hobbies and even what they do in their spare time. For budgetary reasons, we will apply the method "one day in the life of", which is based on an observation process to know these variables.

Figure 1. Communication campaigns could be different according to the objectives set by the institutions or companies.

So, with the audience defined and the budget assigned, the next step is to work on what we want to achieve. Our strategy can be one of more visibility, but it can also be to attract new clients in a tennis academy, sell tickets to a tennis tournament or get contacts (engagement) for promotional purposes. According to the objective, we have four options to invest in Internet advertising:

- Cost per 1,000 views.
- Cost per engagement.
- Cost per clic.
- Cost per acquisition.

It is extremely important to be clear about the purpose of a campaign, because with the wrong choice of a channel, objective or investment mode, the results can be very different from the goals initially proposed.

The last thing we have to define is the platform by which we will carry out the campaign. Yes, we said it was online, but not defined whether it would be through social media, search engines, websites or the institutional portal. Although there are many media choices, a small budget with the right strategy can still involve the many media options.

In today's world, the best cover letter for an entity is the website, which must be linked to social networks. In websites where the vision, values and objectives are exposed, it also offers the facility of creating a blog (Tironi and Cavallo, 2004), a space that serves to achieve better positioning of the web in search engines and also transmit its own content. That information disseminated by social media helps to gain media, that is, tv channels, radio programs or newspapers becoming multipliers of that message that we want to carry, as long as the content is presented in an attractive way for the public.

So, having our social media accounts and the institutional web, and taking into account that we will work to attract others, making use of keywords, tags, etc., we have to invest in different websites that our public visit, search engines and even a small boost investing in the networks would not hurt.

RESULTS

Once we have distributed our budget in the different media and we have executed it through weeks or months of digital advertising, it is time to measure the results, depending on the type of campaign we have worked on. The measurement tools can also be different, although if it is about sales it is much easier to measure. If the objective was to make the brand visible or expand its reach in the public then it can be verified with the number of people who enter the institution's website or those who interact on social networks per day, or current followers compared with those that existed in the period prior to the execution of the strategy.

These measurements are possible thanks to constant monitoring within each social network or with the hiring of software that is responsible for extracting that data.

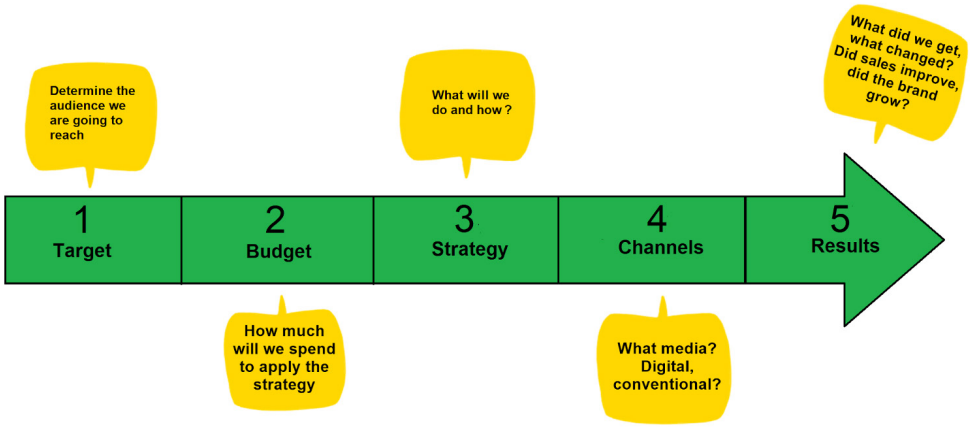

Figure 2. The analysis after the end of the campaign is crucial to know the results that have been obtained.

The exposure of the brand in the traditional media also counts, it even affects the image of what is promoted, since it means that our strategy crossed digital borders and reached a larger audience than we planned.

CONCLUSION

Along with the application of a good marketing and public relations strategy, the tender care of the brand must always be present. With the democratization of communication (Venturino, 2011), users are more likely to express their considerations about a product or current service, which can multiply to create a reputation by itself.

That is why good customer service still works much or better than advertisement, because by offering a good deal, the client becomes a spokesperson for that positive experience, which will reflect to other people as well.

Changing a negative perception is one of the most difficult challenges faced by marketing and public relations, so preserving a good image is already a plus in the success of any communication strategy.

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COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 10-12.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.47

Playing tennis in hot environment: Applied strategies and new directions

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ABSTRACT

Many tennis competitions are held in hot ambient conditions, which can negatively affect endurance, mental and cognitive functioning and/or motor performance. The purpose of this article is to take stock of the physical techniques and psychological strategies that tennis players can use to counteract the negative effect of the heat. In addition, a new direction based on the mindfulness technic is proposed in this article.

Key words: tennis, heat, strategies, cooling, attention, performance

Received: 2 February 2021

Acepted: 10 March 2021

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INTRODUCTION

Performing a sport such as tennis in the heat is physically demanding due to reduced neuromuscular function, increased individual's core temperature, altered skeletal muscle metabolism and increased cardiovascular strain due to thermoregulation (Douzi, Dupuy, Theurot, Smolander, & Dugué, 2020; Nybo, Rasmussen, & Sawka, 2014). Moreover, because of the heat, psychological strain via arousal (Nielsen, Hyldig, Bidstrup, Gonzalez-Alonso, & Christoffersen, 2001), reduced motivation (Bridge, Weller, Rayson, & Jones, 2003), increase in negative affects (Gaoua, Grantham, Racinais, & El Massioui, 2012) and decrease in positive affects (Robin et al., 2019) can negatively influence sport performance. Indeed, the latter authors showed that a hot environment can decrease athletes' accuracy in a task requiring concentration. Finally, heat stress can promote the appearance of peripheral muscle fatigue during prolonged aerobic exercise (Crewe, Tucker, & Noakes, 2008) and the early onset of mental fatigue when performing highly cognition-demanding attention task (Qian et al., 2015). Attentional processes are very important components of successful performance in tennis. However, as the level of stress due to heat, athlete's temperatures and game complexity increase, attentional resources are progressively drained. It seems therefore important to use strategies that allow better regulation and better adaptation to the hyperthermia, induced by exercising, and the decrease in attention functioning caused by the heat (Coudevylle, Sinnapah, Robin, Collado, & Hue, 2019). Racinais et al. (2015) argued that physically active acclimation (e.g., from 5 to 14 days before competition) under heat stress is the "most important intervention one can adopt to reduce physiological strain, optimize performance (during training and competition in the heat) and reduce the risk of serious heat illness." In addition, fluid ingestion is really important because hot environments lead to increased sweating caused by physiological thermoregulatory processes (Schlader, Simmons, Stannard, & Mundel, 2011) that induce dehydration that is accentuated during exercise (Ando et al., 2015). Moreover, cooling can be efficient strategies for tennis players performing in the heat before (pre-), during (per-), and/or post match (post-cooling) as illustrated in Figure 1.

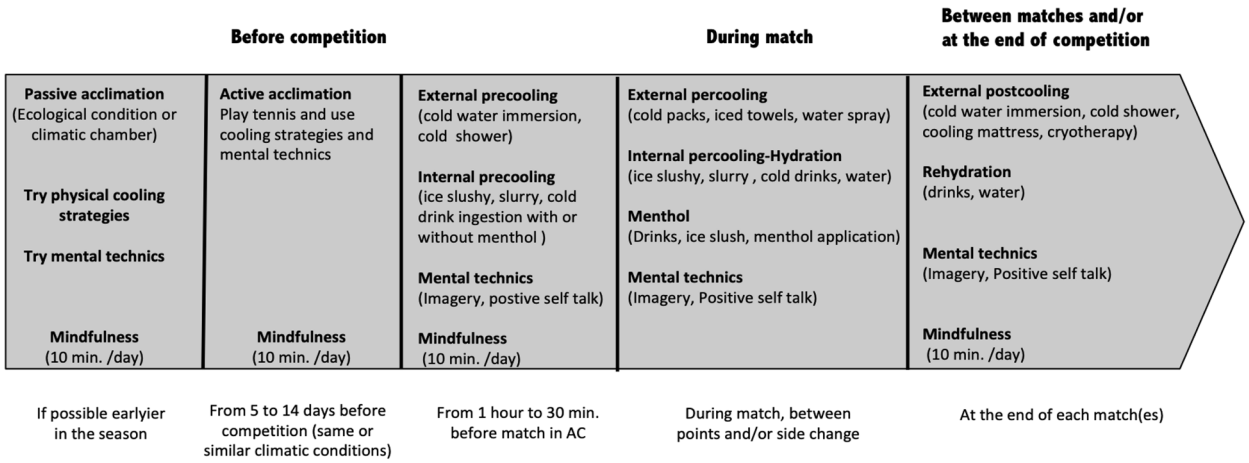

Figure 1. Examples of strategies that tennis players can use in the heat

Cooling strategies are generally classified as internal (e.g., ice slushy, slurry, cold drink ingestion with or without menthol) or external strategies (e.g., cold water immersion, cooling vest or garments, ice towels, neck cooling, cool showers, cold pack, menthol application or water spray), that have been shown to reduce core and skin temperatures, that can improve performances in athletes performing in the heat (Douzi et al., 2020).

Recently, Coudevylle and collaborators (2019) evoked that the use of mental or psychological skills training can improve cognitive and motor performances in the heat. For example, Barwood, Thelwell, and Tipton (2008) showed that a training set of four psychological skills (positive self-talk, mental imagery, goal setting, and arousal regulation) increased motor performance (90-minute "time trials") in a hot environment. Positive or motivational self-talk is a top-down regulation strategy that requires tennis players to continuously re-appraise negative self-talk with self-contextualized motivational and instructional statements that include cue aiming and focusing or directing attention such as 'focus on the ball trajectory', technique, strategy, and kinesthetic attributes of a skill. Positive self-talk, used in hot environment, can help tennis players to actively reformulate negative statements (e.g., 'I'm tired', 'I'm going to stop, it's too hot') to motivational and positive statements (e.g., 'I can do it', 'It's not so hot, I can play and win').

For example, using a two weeks motivational self-talk intervention, Wallace et al. (2017) showed motor (endurance capacity) and cognitive (working memory, attention, speed processing) task performance improvements in the heat. Finally, researchers recently evoked the potential beneficial effect of mindfulness in sports performed in the heat (Coudevylle et al., 2019). Mindfulness corresponds to a state of awareness and attention to the present moment, which includes attention to environmental, mental, and physical stimuli without making evaluations. This mental technic, which is composed of three components: 'Awareness' of current emotions, bodily sensations, and thoughts, non-judgmental 'acceptance', and 'commitment' to goal-relevant attention focus and behaviour, is frequently used by athletes including tennis players. Haase et al. (2015) found that mindfulness intervention changed the way athletes' process interoceptive afferent informations and improved their ability to regulate anxiety related to unpleasant though, sensation and feelings.

The relation between mindfulness and tennis performance could refer to sense of control over oneself and the heat, and to the altering perceptions of barriers or distractions that would potentially concerned heat stress and its consequences such as fatigue or thermal discomfort (Coudevylle et al., 2019).

CONCLUSION

Heat stress and the hyperthermia caused by playing tennis in the heat induce physiological and cognitive (e.g., attentional) strains that can degrade tennis performance and leading to potential risks for the players performing in hot ambient conditions. The use of strategies to counteract the effects of heat stress on tennis player performance seems therefore to be necessary. Active acclimation, cooling intervention, acute hydration, or positive motivational self-talk seem to be interesting strategies to explore in order to counteract the negative influence of the heat (increase of fatigue, thermal discomfort, decrease in motivation and concentration) and

lower the perceived load of high temperature. Finally, the use of mindfulness, which can benefit attentional processes, could be potentially useful during tennis training and competitions performed in hot environment.

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COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 13-15.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.48

Structural constants of the internal logic of tennis

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ABSTRACT

This article discusses the factors that determine the structure of the sport of tennis based on the theories of motor action. It outlines a framework of tennis by reviewing the major theoretical contributions published and by identifying the most unique and specific elements of the game that every coach or athletic trainer needs to know when teaching the tennis concepts or planning and optimizing its training.

Key words: internal logic, motor action, tennis theory

Received: 20 February 2021

Acepted: 22 March 2021

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INTRODUCTION

In the field of tennis teaching, coaches, physical trainers and other members of the multidisciplinary team should have a more or less broad epistemological knowledge of the factors that shape the structural uniqueness of the game of tennis.

In the present article we intend to approach the functional structure and the determinants of the game of tennis through the concept of internal logic, introduced in 1981 by Pierre Parlebas in its theoretical postulate on motor praxeology. This discipline, in the words of Lagardera (1994, p.23) tries to "explain the nature of the motor actions of games and sports, classify them, establish taxonomies and expose their internal logic". The internal logic, self Parlebas (1981, p.302) himself defined internal logic as: "the system of features that are relevant to a motor situation and the praxeal consequences that this system results in the game action ". We would say that the internal logic of tennis determines the phenomena, behaviours, and relationships that emerge from the very essence of the game and set up their motor action. The game action or motor action, can be defined as the perceptual processes, cognitive and lastly motoric that occur specifically in a sport enabling the cycle: perception (see the ball), decision (what to do with the ball) and execution (how I hit the ball).

REVIEW

The model proposed by Parlebas, has been very recognised and developed in the field of physical education by authors such as Lagardera (1994; 2003) or Lavega (2003). Also, other noteworthy contributions are those of Hernandez-Moreno (1994; 1995; 2000) in the area of sports initiation and it has been applied to a variety of sports such as futsal (Hernandez-Moreno, 2001), soccer (Marques, 2017), volleyball (Fotia, 2012), handball (Friedrich and Fagundes, 2020) or basketball (Sautu et al., 2009).

In the tennis context, Crespo (1990) presented a proposal of a functional structuring of the game, largely based on the model from Hernandez-Moreno (1987) which included in its categorisation the following parameters: space, time, rules, motor communication, motor strategy, technique and materials.

In our proposal we will focus on the structural constants classified by Parlebas (1981), and subsequently by Lagardera (1994): participants, space, time, implement and mobile. We consider the following elements: motor communication, motor strategy and technique mentioned by Crespo (1990) as inherent to the game action or the functional structure that may be addressed in later work (Figure 1).

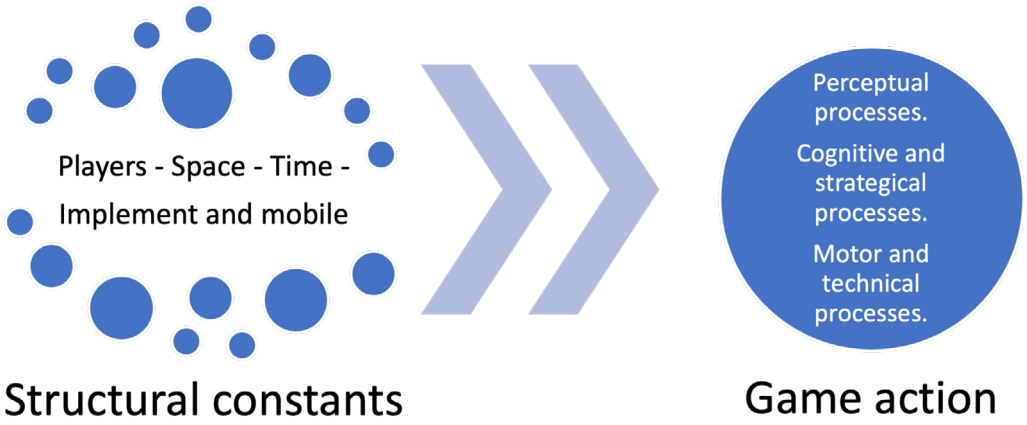

Figure 1. Structural constants and game action

DETERMINANT STRUCTURAL CONSTANTS IN TENNIS

The participants

Tennis is a socio-motor sport, since it is developed through motor interactions between players. On the contrary, in psychomotor sports the participant does not interact with anyone during their practice (for example, swimming). Within the interactions between players, collaborative and oppositional interactions can be distinguished.

Tennis as an opposition sport

In the individual competition it occurs an opposition relationship between the actions and interests of the players. The successes of a player are opposed to the errors of the adversary. When a player wins, the opponent loses. When one player attacks, the opponent defends or counterattacks.

Tennis as a collaborative sport

In the doubles game, two players (partners) collaborate with each other to set up the opposition against the pair of opponents. This collaborative relationship is indirect and is produced from tactics, positions and strategies without the possibility or need for direct interaction.

In certain teaching-learning situations, it is convenient and common to use proposals for collaborative work between players in the form of patterns of play, exchanges and rallies.

Tennis as an alternative interaction sport

Tennis can be categorised within sports where the interaction occurs in an alternative way, in this case through the ball. One's hitting precedes the opponent's hit alternatively.

The space of the game

Tennis as a game with stable spaces and subspaces

Tennis takes place in a limited space. According to the Parlebas classification, the space in sports can be stable and standardised or unstable and a carrier of uncertainty. In the case of tennis, it is obvious that the space is stable and delimited, and the uncertainty can only appear due to weather aspects (wind) or be specific to the surface (irregular boats).

Another of the singularities of the space in the sport of tennis is its organization in subspaces, and its antithetical disposition (Crespo, 1999).

Tennis and the adaptation of the space

The space in tennis can be modified to favour the experience and the learning stages of development. Some studies such as Larsson and Guggenheimer (2013), Farrow and Reid (2020) or Buszard, Reid and Farrow (2017) provide evidence of how the proposed adaptation of spaces and materials of the ITF Play and Stay campaign (2007) has been favourable for tennis learning.

In tennis teaching and coaching, it is also common and recommended that coaches use different modifications of the sub-spaces to favour desired technical-tactical behaviours.

Tennis as a long-distance confrontation duel

Tennis would be part of long-distance duel sports, where the player's target is a certain space on the opponent's playing field. In other duel sports, the target would be in the body of the adversary as it happens in duel sports of zero (judo), reduced (boxing) or half (fencing) distance.

The time

We will adapt the time proposal by Menaut (1982) taking into consideration two differentiated time variables: internal synchrony and external diachrony.

The external synchrony of tennis

Tennis is a sport without time limit, the time is dependent on the score. The different scoring systems can modulate the match length. The playing surface is also an influencing factor on the total time of a match, on clay the length is greater than on a fast court and on grass are found the records of shorter duration (Fernández-García et al., 2012)

Equality between the players will be another component of temporal modulation, so that an even match where the points are distributed between both players in a very similar way will last longer than a match with greater inequality.

The internal diachrony

It refers to the sequential aspect of the game's own actions, at this point, we propose a two-dimensional differentiation:

- **Playing time**

  It is the real time during which the game actions take place, that is, while the players are perceiving, deciding and executing and / or moving, hitting the ball and playing a point. This brings us to another of the structural singularities of tennis, the low percentage of playing time in relation to the total time of a match. According to a review of the characteristics of the temporal structure in tennis, Torres-Luque et al. (2014) established " the actual playing time is between 20% and 26% of the total game time".

- **Game rhythm**

  The rhythm of the game refers to the time that elapses between shots, so that the less time between shots, the more rhythm of the game and more speed of the ball. It is an indicator related to the level of play of the players and the tactical dimension.

Extracorporal objects

The game action in tennis is carried out using two external, specific and singular materials: the racket (implement) and the ball (mobile). The characteristics of these objects are determined by the regulations.

Tennis as an implement and mobile sport

The mobile used in tennis is the ball. Through the ball, the strategic interaction and motor communication of the game takes place. The tactical behaviour of the player is expressed through the ball, in the form of directions, speeds, depths, heights, and spins.

The implement in tennis is the racket, it is used as an extension of the body itself to execute the main motor action of tennis, hitting. It interacts directly with the mobile, and leads to the technical motor expressions of tennis.

Tennis as an asymmetric sport

The characteristics of the implement and the mobile in tennis configure another of its most important singularities, asymmetry. The fact of playing with a single implement and a single ball means that the players have to execute the majority of strokes with one arm and on one of the two sides of the body.

The preference of each player to use one or the other hand in the execution shows their manual laterality. In this area, Loffing (2012) has studied whether there is a certain advantage to develop in the sport of tennis being left-handed. His research shows that there is an increased presence of left-handers in the elite regarding the proportion in the normal population. To explain this significant difference, he proposes two theories that are still under discussion: the negative frequency of left-handers, that is, playing against a left-hander is less common and this entails greater tactical difficulty; and on the other hand, the biological theory, which indicates that there could be certain innate conditions such as faster reaction speeds in the specialization of the right hemisphere, which controls contra-laterally the motor skills of the left arm.

CONCLUSIONS

The theoretical approach to the various elements reviewed in this article helps to understand the uniqueness of the game of tennis and its phenomena. The framework or map of the internal logic of the game of tennis presented can be useful to awaken the reflection of coaches and trainers, as an organizational proposal of contents in coach education courses or can be helpful as a basis for a further in-depth theoretical work.

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COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 16-20.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.49

Adolescent female tennis players: Injury prevalence and prevention

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ABSTRACT

This literature review aimed to identify injury prevalence in adolescent female tennis players, and was conducted in accordance to the PRISMA guidelines (Shamseer et al., 2015). The lower extremity encountered the greatest number of injuries and musculotendinous injuries were the most common injury type. Injury prevalence and the anatomical location of injuries changed with chronological age. Acknowledging the results can help tailor strength and conditioning programmes to target the most prevalent injuries within each age group.

Key words: adolescent, female, injuries, tennis

Received: 18 January 2021

Acepted: 1 March 2021

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INTRODUCTION

Tennis is played by over 87 million people worldwide, making it one of the most popular global sports (ITF, 2019) with a growth in female participation. A literature review was undertaken to identify adolescent female specific injury prevalence and prevention, to help tailor coaching programmes accordingly. Many injury risk factors are unfortunately non-modifiable. It is important for coaches to be aware and take advantage of any risk factors that can be modified. The main injury prevention themes identified from the literature review are presented.

METHODS

The literature review used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Figure 1) (Shamseer et al., 2015). Inclusion criteria involved analysing female tennis players between 10-19 years, published in English between 2009-August 2019 and an evaluation of injury outcomes (incidence, prevalence, type, location, severity). A systematic search was performed utilising Medline Ovid as the primary electronic database and replicated in: Web of Science, Sport Discus, PsychInfo, Scopus and CINAHL, with predefined the keywords and Boolean terms displayed in Table 1.

Table 1

Search Strategy Keywords and Boolean Terms.

Tennis
AND
Girl* OR Female*
AND
Adolescen*
AND
Athletic injur* OR Injur* OR Caus* OR Epidemiol* OR Etiolog* OR Aetiolog* OR Mechanism* OR Preval* OR Inciden* OR Occur* OR Propor* OR Distribut* OR Populat* OR Risk factor* OR Predispos* OR Acciden*

*Truncation: used to identify all possible endings of the key term; *AND:* searches for two terms and limits the search; *OR*: searches for two or more terms and widens the search

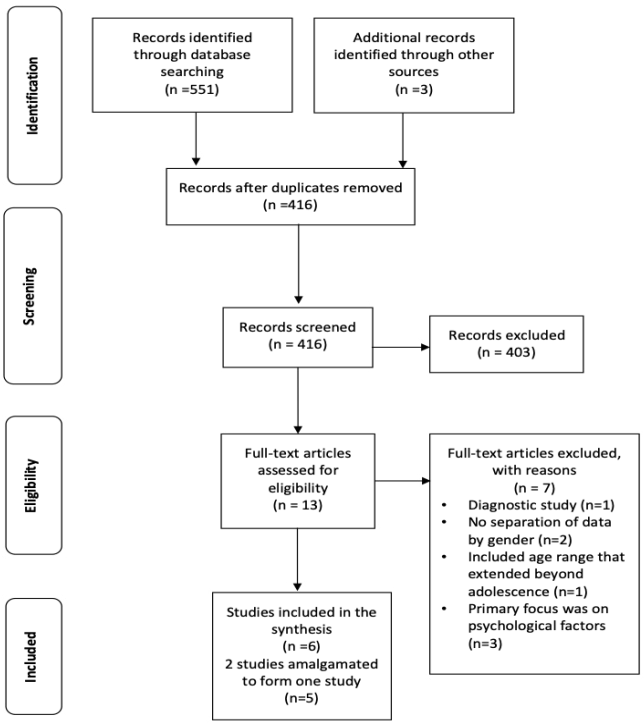

Figure 1. PRISMA flow chart of literature retrieval and selection.

DISCUSSION

Table 2
Characteristics of the reviewed studies.

Reference	Objective	Study Design	Study Population	Age of Participants (Years; Mean ± SD)	Injury Rates
Correia et al., 2016	Present a profile of medical complaints in ITF junior and Pro circuits tournaments	Prospective Cohort	N= 816 Male: 474 Female: 342	Male: 16.28 ± 0.56 Female: 15.72 ± 0.41 Total: 16.06 ± 0.47	Complaints (95% CI): Per match: 0.43 (0.29-0.56) Per 1000 games: 23.00 (15.72-30.28) Per 1000 hours: 337.59 (220.32-447.27)
Hjelm et al., 2010 Hjelm et al., 2012	Survey of injuries and risk factors in junior players from a Swedish local tennis club	Prospective Cohort	N= 55 Male: 35 Female: 20	Male: 16.10 ± 3.0 Female: 14.20 ± 2.0 Total: 15.40 ± 2.8	Incidence per 1000 hours (95% CI): 0.5 (0.26-0.67)
Gescheit et al., 2012	To profile multi-year injury incidence and severity trends in elite Junior tennis players from a national program	Prospective Cohort	N= 101 Male: 58 Female: 43	13-18	Incidence per 1000 hours (mean ±SD): 2.8 ± 0.0
Jayanthi et al., 2009	To Investigate the association between medical withdrawals and age, sex, match volume and match type	Retrospective Cross-sectional Cohort	N= 28,336 (exposures) Male: 14,108 Female: 14,105 Unavailable: 123	12-18	Medical withdrawals per 1000 match exposures: 14.0
Kovacs et al., 2014	To analyse a series of demographic, technique, injury and training related questions in competitive Junior tennis players	Prospective Cohort	N=832 Male: 356 Female: 476	10-17	/

INJURY CLASSIFICATION, TYPE AND ANATOMICAL DISTRIBUTION

Acute, traumatic injuries accounted for 34.5-44.4% and overuse injuries explained up to 55.6-65.5% of reported of female injuries. Overuse injuries were more frequent in the upper extremities (75%) than the trunk (67%) or lower extremity (39%). Injury severity analysis reveal nearly 50% of female injuries were classified as severe and required >28 days to return to participation (Correia et al., 2016; Hjelm et al., 2012). Musculotendinous complaints were the most common injury representing 71.3% of all female injuries, followed by joint injuries (17.2%). Ligaments were the most common injury within a joint, representing 12.1% of all injuries. The anatomical distribution of injuries revealed the lower extremity was the most prevalent injury site (41.4%), followed by the upper limb (29.9%) and the lower back/ trunk (22.2-25.90%). When analysed more acutely by sub-regions the lower back/lumbar spine accounted for 12.1% of trunk injuries, the shoulder recorded the highest number of injuries in the upper limb (16.7%) and the knee represented 14.9-18.5%, of total lower limb injuries in female adolescent players (Correia et al., 2016; Hjelm et al., 2012). The results of anatomical injury location is presented in Table 3.

AGE

Of particular interest to coaches is the reported increase in injury prevalence with chronological age (13-18 years) from 2.0 ± 0.2 to 2.9 ± 0.1 injuries per 1000 exposure hours (Gescheit et al., 2019). In adolescents 14 years and under the shoulder was the most dominant injury location, followed by the hip/groin (Gescheit et al., 2019; Kovacs et al., 2014). The knee was particularly prevalent in the under-16 category (Kovacs et al., 2014). However, a consistent observation between 14-18 years of age was the high prevalence lumbar spine injuries (Gescheit et al., 2019).

THE SHOULDER

A considerable proportion of injuries occur in a player's dominant shoulder (Fernandez-Fernandez et al., 2019) and are overuse in nature (Ellenbecker et al., 2009). The high level of repetition involved in tennis places the shoulder and particularly the rotator cuff at risk of sport specific muscular adaptations (i.e., a muscular imbalance and a loss of internal rotation ROM) (Fernandez-Fernandez et al., 2019). The research suggests that from an early age players are developing a high incidence of shoulder related injuries. Therefore, should be a prevention focus as early as possible in players.

LUMBAR SPINE

The spine is at considerable risk of injury, particularly if the correct technique is not executed (Salzmann et al., 2018). The serve is frequently associated with the development of lower back pain in adolescent players, due to the high-level of muscular activation and mechanical loading. The kick serve, commonly introduced between 12-15 years of age (Campbell

Table 3
Injury Anatomical Distribution.

	Correia et al., 2016	Hjelm et al., 2010; Hjelm et al., 2012		Gescheit et al., 2019	Kovacs et al., 2014
	Number of complaints/Total complaints (%)	Incidence per 1000 hours (95% CI)	Incidence per 1000 hours (Mean ± SD)	Percentage of Injuries (%)	Incidence per 1000 hours (Mean ± SD)
Foot	6/174 (3.4)		1.9 ± 0.4	2 – 8	1.9 ± 0.4
Ankle	9/174 (5.2)		2.3 ± 0.3	9 – 17	2.3 ± 0.3
Knee	26/174 (14.9)		2.0 ± 0.2	8 – 22	2.0 ± 0.2
Thigh	26/174 (14.9)		1.6 ± 0.1	2 – 5	1.6 ± 0.1
Hip/Groin	0		1.4 ± 0.2	0 – 5	1.4 ± 0.2
Lower back	21/174 (12.1)		3.9 ± 0.2	4 – 17	3.9 ± 0.2
Shoulder	29/174 (16.7)		2.6 ± 0.2	11 – 25	2.6 ± 0.2
Elbow	8/174(4.6)		1.7 ± 0.3	3 – 4	1.7 ± 0.3
Wrist and Hand	8/174 (4.6)		2.4 ± 0.2	9 – 10	2.4 ± 0.2
Head/Neck	5/174 (2.9)		0.5 ± 0.1	0 – 1	0.5 ± 0.1
Other	0		0	10 - 17	0
Upper extremity	52/174 (29.9)	0.1 (0.03-0.25)	6 /27 (22.2)		
Lower extremity	73 /174 (41.4)	0.3 (0.16-0.50)	14 /27 (51.9)		
Lower back/Trunk	45 /174(25.9)	0.2 (0.04-0.29)	7/27 (25.6)		

et al., 2013), potentially contributes to the high incidence of lumbar spine injuries. A commonly observed predisposing factor is muscular imbalance. Injury prevention should focus on extensive core stability, involving both flexor and extensor muscular development. Rotational exercises are required to build resilience to the high repetitive demands (Ellenbecker et al., 2009).

HIP AND GROIN

The loading, multidirectional movements and extreme range of motion that are demanded of the hip during tennis, place the joint and the surrounding soft tissue structures at risk of injury (Safran, 2014). The hip joint muscles play a vital role in the transfer of forces through the kinetic chain. Hip muscle strength can impact the load through the joint, altering its function, impacting injury risk, not only to the hip but also the lower back and knee (Ellenbecker et al., 2009).

KNEE

A high prevalence of knee injuries was observed particularly in females of 16 years of age. Many knee injuries share similar risk factors that can be targeted. Both ligaments injuries and patellofemoral pain are often associated with muscle weakness, and /or imbalance and limited flexibility in the knee and pelvic-femoral region. A decreased level of neuromuscular control around the knee has been reported in female athletes during maturational growth (Hewett et al., 2004), potentially contributing to the increased level of knee injuries witnessed.

Integrating core stability training into an athletes training has been demonstrated to be crucial in preventing and reducing injuries, particularly to the lower limb. It has been suggested that the core is the foundation of the kinetic chain and facilitates the transfer of energy from the lower to the upper extremities (Huxel-Bliven & Anderson, 2013) which is pivotal in tennis and for enhancing performance. The exercises below focus on some core exercises that provide stability for the tennis player (Huxel-Bliven & Anderson, 2013). The subsequent region specific exercises, focus on the most prevalent female adolescent injuries identified from the literature review. These exercises may be useful to incorporate into an adolescent female's injury prevention strength and conditioning routine.

Core stabilisation exercise:

Bridge:

- Trains the back, abdominal and gluteal muscles simultaneously
- Lie on your back with knees flexed to 90 °
- Push pelvis up
- Ensure the pelvis and torso are in one line

Figure 2. Brige.

Dead bugs:

- On your back place hips and knee at 90°
- Lower opposite arm and leg
- Keep the small of your back pushed into the ground by activating your core and do not compensate by arching the back
- Develops lumbopelvic stability

Figure 3. Dead bugs.

Superman exercise:

- In four point kneeling with a neutral spine
- Extend opposite arm and leg
- Engage core muscles and do not hyperextend their spine when extending the leg
- Targets the gluteal, hamstrings, external obliques and back muscles

Figure 4. Superman exercise.

Side Plank:

- Lying on side
- Lift up into a side plank with feet stacked or one foot in front of the other
- Ensure a straight line from feet to shoulders
- This targets the Abdominal muscles (external obliques, rectus abdominus), back muscles and gluteus medius

Figure 5. Side Plank.

Many exercises focus on one particular region but can be beneficial for other anatomical locations due to the pivotal role of the whole kinetic chain in tennis. Below are some region specific exercises.

Shoulder Emphasis:

- Lawnmower exercises: initiating the exercise with the lower extremities increases scapular muscle activation and recruitment (Funk et al., 2018)
- The step-up with resistance band: requires hip extension and this reinforces gluteal and sequential activation throughout the kinetic chain. The resistance band also reinforces rotator cuff muscle activation (Funk et al., 2018).
- Shoulder external rotation with resistance band: providing support to the working limb will also ensure selective recruitment of the rotator cuff muscles (Funk et al., 2018)

Lower extremity

- Clams and Reverse Clams: to target hip Internal and external rotation, perform on both sides to work on achieving symmetrical hip rotational strength in the lower limbs (Ellenbecker & Pluim, 2009).
- Multidirectional lunge: To strengthen hip, knee, ankle and core stability while also challenging dynamic balance, required for multidirectional movements in tennis (Samson et al., 2007; Huxel-Bliven & Anderson, 2013)
- Single leg squat: Focuses on improving neuromuscular control particularly of the knee (Hewett et al., 2004), targets the gluteal muscles, while also challenging core stability. Poor gluteal strength has also been linked with reduced shoulder performance in overhead sports (Funk et al., 2018).

CONCLUSION

Adolescent female players need to be provided with core strength and conditioning and also more specific strength and conditioning that is tailored to prevent the most prevalent age related injuries that have been reported in the literature. Further research focusing on adolescent female injury is recommended, as the current paucity of research impacts on evidence based targeted injury prevention programmes for this group of tennis players.

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RECOMMENDED ITF TENNIS ACADEMY CONTENT (CLICK BELOW)

COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 21-24.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.51

Training for Lateral Acceleration

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ABSTRACT

Tennis movement can be characterized by primarily short lateral bursts over typically 3-4 m initiated by a reactive decision step. Lateral acceleration depends on unilateral movement, or specifically, the outside leg to enhance ground reaction force (GRF). Few studies have been conducted for the development of lateral speed with emphasis on unilateral training. A simple one-leg test for unilateral strength is presented. Exercises for improving lateral acceleration are presented.

Key words: lateral movement, acceleration, unilateral leg strength, change of direction, training

Received: 22 January 2021

Acepted: 19 March 2021

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INTRODUCTION

Tennis movement can be characterized by primarily short lateral movements initiated by a reactive decision step (aka, split-step). About 70% of tennis movement is lateral and 20% of tennis movement is forward (Weber et al., 2007). Movement can be improved by: 1) strength-speed training, 2) technical training, 3) and anticipation training. Kovacs (2009) summarized the importance of lateral movement training. This article addresses on-court lateral acceleration with regards to strength-speed training.

Movement and Acceleration

It has been estimated that the average professional on clay courts runs to only 5% of shots where distance > 4.5 m (Ferrauti, & Weber, 2001). SI.com staff (2015) tracked movement of 4 ATP players and found their movement per point was 8 - 14 m which depended on playing style and rally length. At the 2017 Australian Open, the average rally lasted 4.47 and 4.85 shots and 5.44 and 5.93 s for women and men, respectively (Carboch et al., 2018). Top ATP (N=34) and WTA (N=44) players had mean rally lengths of 4.21 and 4.06 shots with a player range from 3.2 – 5.4 during September 2019 - September 2020 (Sackmann, n.d.a; Sackmann, n.d.b). It has been reported that inter-point time is 25-45 s and varies with individuals (Bialik, 2014; Sackmann, 2020). From data, it is estimated that a run > 4.5 m occurs once every 3 - 3.5 min.

Although runs > 4.5 m occur infrequently, high acceleration and deceleration are more common. Hoppe et al. (2014) found peak running speeds for adolescent players (12-14 y.o.) was 4.4 ± 0.8 m/s (9.8 mph). Players exceeded 3 m/s (6.71 mph) once every 5 min or only 18.5 times per match. High acceleration (> 2.0 m/s2) and deceleration was 51.7 and 47.0 times per match, respectively or 0.6/min each or once per 1.7 min. High acceleration at once per 1.7 min is twice as frequent as running distances > 4.5 m as reported for professional players.

Clearly, initial acceleration is more important than top end speed. In addition, anticipatory cues can optimize movement and reduce acceleration requirements by responding earlier to a stimulus. Lateral acceleration depends on unilateral movement, or specifically, the outside leg to enhance GRF (ground reaction force). Technical footwork training should involve training unilateral explosiveness to improve RFD (rate of force development). In the 5 - 10 m interval, an athlete can reach 70% of top end speed (Duthie, Pyne, Marsh, & Hooper, 2006).

Lateral Acceleration

Of interest is the acceleration of top professional tennis players. Djokovic and Nadal have been measured at 4.81 and 4.70 m/s2 in acceleration to the forehand (Eng & Sundar, 2020). Nadal was measured at 4.30 m/s2 in acceleration to the backhand. Comparatively, Usain Bolt in a starting 4-point stance has been calculated to reach an initial acceleration of 9.5 m/s2 (Gómez et al., 2013). A sprinter's first 3 steps involves mostly horizontal force (Dintiman, 2020). However, Djokovic and Nadal are sprinting repeatedly and Bolt is sprinting once, and the distances in tennis and the 100 m sprint do different demands. On wide balls, Djokovic can typically achieve stride lengths of 2 m and stride frequencies of 4 steps/sec (Eng & Sundar, 2020). Acceleration was not uniform but dependent on unilateral RFD. An athlete may initially drive from either leg unevenly as leg force may not be equal for either leg. In addition, legs may be in different phases such as the takeoff or touchdown positions.

Few studies have been conducted with the development of lateral speed. Players typically run 0.25 to 0.50 m more to the forehand side than the backhand side (Weber et al., 2007). Therefore, training acceleration to the forehand may be more important for players who prefer to hit a dominant forehand. Hewit et al. (2012) discussed unilateral leg movement in linear and lateral jumping and running. Largest leg strength differences were found in lateral movement (single leg countermovement lateral jumps or SLCM-L) but it was suggested that up to 15% difference was normal and acceptable. That is, an athlete might be 15% weaker in one leg than the other without detrimental loss of speed. Unlike many

field sports which involve cutting at 20-60˚ where asymmetric leg strength is not consequential, tennis, however, differs and requires greater lateral movement and 180˚ COD (change of direction).

In lateral movement, most force is generated by the outside leg which is farther from the intended direction. After the stroke, recovery to a favorable court position requires where the legs switch roles. Tennis players can be tested on the outside leg moving either to the forehand or backhand side. Using unilateral strength and plyometric training to train unilateral leg force production may improve athletes with weaker movement to one side.

Testing Method

Measurement of initial leg power can be correlated to leg strength. Hewit et al. (2012) tested various vertical and lateral jumps finding the largest leg discrepancies were SLCM-L (single leg countermovement jump – lateral). Modest correlation between lateral power and COD has been found but lateral jumps were not the strongest predictors of COD speed (Lockie et al., 2014). Lockie et al. (2013) developed tests for COD cutting at 20 – 60˚ which is valid for many field sports but tennis requires 180˚. COD has been found to be related to the outside reactive leg strength (Young et al., 2002). Athletes averaging 24% stronger in the right leg, were 4% faster moving to the left. Habibi et al. (2010) found single leg hop power was correlated with 10 m sprints. Therefore, unilateral leg reactive strength is important for tennis.

Figure 1 shows a SLLJ (single leg lateral jump) in which a countermovement is allowed and the takeoff and touchdown leg are the same. The SLLJ can off either leg can be a test for unilateral leg strength. Measurements should be on the outside edge of the foot or shoe (green line). Lateral jumps in both directions should be executed and measure from a best of three jumps.

Figure 1. Single leg lateral jump (SLLJ) test with countermovement. Note the same leg is used for takeoff and touchdown.

EXERCISES

Lateral Wall Holds and Drives

Lateral wall drills allow the athlete to shift the center of gravity applying horizontal lateral force, while maintaining balance using a wall or fence. In the lateral wall hold (Figure 2), the athlete leans 30˚ sideways into a wall placing a hand out for support or the athlete can lean on the shoulder. The athlete lifts either knee up to the hips and maintains the angle for a few seconds and switch to the other leg and hold that position for a few seconds. The athlete repeats leaning on the other side. Once the athlete is proficient, the athlete can do lateral wall drives in sets of 2-6 rapid alternating steps. The athlete then switches to the other side.

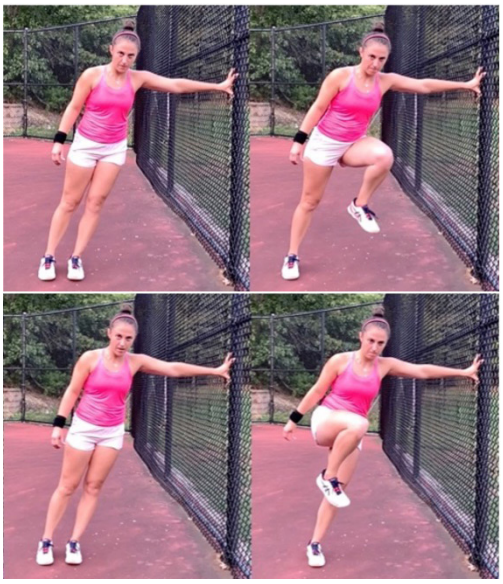

Figure 2. Lateral wall hold and alternating drives.

A third wall drill (Figure 3) is the load and crossover hold which brings the outside leg across and up. Force production is more powerful and angled than in the lateral wall hold. Athlete should start low with the outside leg at an angle to push off. The inside shin is slightly tilted. The athlete drives quickly into the wall. Both arms can be placed on the wall or fence. Hold the starting and ending positions for a few seconds. Sets of 10 can be done on both sides.

Figure 3. Load and crossover hold.

Hops + Bounds + Sprints

A hop is defined when the take-off and touchdown is done off the same leg and the distance covered is relatively small. A jump can be two-leg or one leg for both take-off and touchdown covering larger distances than a hop. A bound is defined when the take-off leg and touchdown leg are alternating legs.

Most decision steps in tennis involve a vertical component with landing first on the leg farther away from the intended direction and the other leg taking a lateral step with the toe pointing towards the intended direction. For training, the following exercises are useful:

A. Vertical single leg hop + lateral bound (alternating), shown in Figure 4

B. Lateral single leg hop + lateral bound (alternating)

C. Vertical single leg hop + lateral bound + short sprint opposite direction

D. Lateral single leg hop + lateral bound + short sprint opposite direction, shown in Figure 5

Figure 4. Vertical single leg hop + lateral bound (alternating).

Figure 5. Lateral single leg hop + lateral bound + short sprint opposite direction.

In these exercises, the single leg hops mimics the initial decision step landing but trains single-leg RFD for the lateral bound. One purpose of varying vertical and lateral single leg hops is the variability in tennis movement. At times a player may be starting from a moving position or a standing position as in the serve return. In standing positions, the initial decision step may have a more vertical force. Other times a player may be still recovering into the court at higher velocities, where a decision step may involve a greater horizontal force. In such case, greater forces are required for COD. Therefore, lateral hops combined with lateral bounds can help train those COD movements.

Figure 6. Bungee-assisted lateral explosion.....

Another important concept is developing appropriate leg stiffness with short GCT or ground contact time (Ferris et al., 1999; Morin et al., 2007). Therefore, rapid movement quality with short GCT is important. In Figure 5, the athlete rapidly shifts weight inside after the lateral bound to sprint in the opposite direction of the bound. Exercises A (Figure 4) and B can be done with 12-20 reps. Exercises C and D (Figure 5) can be done in sets of 6-10 reps with a short break between reps. Exercises C and D may be combined with other COD and agility exercises to train repeated sprint ability (RSA).

Contrast Training

Contrast training refers to varying loads with similar movement or exercises. A classic contrast training for speed involves running uphill and downhill at modest angles as not to alter running mechanics (Dintiman, 2020). Bungees and resistance bands can provide assistance or resistance forces without significantly altering lateral movement. Figure 6 shows the bungee-assisted lateral explosion. Anchor the bungee high so it pulls the athlete laterally and upwards. The athlete makes a decision step into a crossover step with 2-3 extra accelerating strides. In the bungee-resisted lateral explosion, the bungee is anchored at the bottom of the fence and the athlete explodes upwards and away from the anchor into a crossover step with 2-3 extra accelerating strides. An athlete may do sets of 8-10 reps of resisted and assisted accelerations.

CONCLUSIONS

Tennis movement is mostly lateral but athletes may have differences in movement to either side which should be trained. Tennis players who use the forehand weapon to cover most of the court may require higher acceleration to the forehand. Little research exists on unilateral reactive leg strength training which has implications in tennis. Physical

training should require elastic unilateral reactive leg strength training and COD movement. Tennis-specific physical on-court training for lateral acceleration was tackled with regards to technical training. A single leg lateral jump test is recommended but needs to be correlated to actual lateral acceleration in future studies. Lateral wall exercises, hop-jump-bound exercises and contrast training may help tennis players improve lateral movement.

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COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 25-27.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.52

Kinematic differences between professionals and young players in the tennis serve

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ABSTRACT

The aim of the present study was to measure and examine the differences in lower limb kinematics between the flat, slice and topspin serves, in the kinematic features of the lower limbs, at two different times of the service movement, maximum knee bending and point of contact of the racket with the ball, in 12 young tennis athletes, aged 12-16 years and in 12 professional players that they were playing on the main draw of Roland Garros. The results showed no significant differences in time between the three types of service in young athletes. Comparing the time of young athletes 34.56ms with the time of high level athletes with 30.67ms, the results showed that the professionals performed the service faster than the young athletes having a significant difference.

Key words: flat, slice, topspin, tennis serve, biomechanics, young tennis athletes, professional tennis players

Received: 20 January 2021

Acepted: 15 March 2021

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INTRODUCTION

Tennis serve has attracted the attention of research because it is the most important stroke that starts the game (Cross & Lindsey, 2005). Although it has been well documented that service performance is related to upper extremity movement, very little is known about the impact of lower limps. There are very few research studies that have explored the kinematic characteristics of serve movement in young tennis athletes and much less studies compared the three basic serve types, namely the flat, slice and topspin (Abrams et al., 2011; Elliott, et al., 2009; Reid, Elliott, & Alderson, 2008; Elliott & Wood, 1983; Elliott, Fleisig, Nicholls & Escamilla, 2003). The purpose of this study was to measure and examine the differences that may exist between the three different types of service, flat, slice and topspin, in the kinematic characteristics of the lower limps and in particular the beginning of the take-off which coincides with the time point of contact of the racket with the ball.

As the mechanism of «leg drive» is an important factor for the efficiency and speed of service, the present study examines for the first time in young athletes the kinematic characteristics of the lower limbs. It is expected that by improving the movement of the legs, a better driving of the foot can be produced, which can enhance the rotation of the shoulder resulting in a better service, as concluded by Girard, Micallef & Millet, (2005).

METHODS

Twelve (6 males, 6 females) right handed young tennis players, aged 12-16 participated in this study, that are playing in tournaments of the Hellenic Tennis Federation (age: 13,8±1,22 years, height: 167,5±10,11 cm, mass: 55,20±11,15 kg) and 12 professionals who participated in Roland Garros, 6 men and 6 women.

Instrumentation

The Optitrack kinematic optical analysis system (Natural point Systems Inc., USA) was used to conduct the research. The system uses 9 infrared cameras (Flex 3, Natural Point Systems, USA) with a sampling frequency of 100 Hz, 0.3 Megapixel resolution (640 x 480 pixels). The system software Arena (V.1.15, Natural Point Inc., USA) was implemented for all measurements.

Experimental set-up

The subjects performed a standard warm-up, followed by a 10-minute working out of all three different serves. The athletes then performed the three different services, flat, slice and topspin with three attempts each, which were recorded. The best attempt that was considered representative to analyze was that in service, the ball had to pass over the line of a 0.914m-high tape.

The three-dimensional space was first calibrated using a calibration wand. A total of 34 markers were placed on the head, the trunk, the shoulders, the elbow, the wrists, the pelvis, the hip, the knee, the shank and the feet. Based on the 3D coordinates of the reflective markers, the skeleton was represented in all frames of motion throughout the 3-D space. Skeleton motion was digitally stored in video format. Hence, video files were then used to calculate the time of each type of serve.

For professional athletes, video analysis was used and time was measured using the max TRAQ Lite.

RESULTS WITH DISCUSION

The present study aimed to focus on the lower limps and biomechanically analyze the time from the maximum knee flexion to the point of contact with the ball in the three different services, flat, slice and topspin, in young athletes aged 12-16 and high level professional athletes who participated in the main draw of Rolland Garros.

From the results in figure 1, we conclude that the flat service took the shortest time 33.67ms and this is attributed to the fact that it is used mainly as a first service, which means that it is performed with more power and speed. The slice service took 34.92ms and the topspin 35.16ms due to the higher knee flexion during the preparation phase of these services, which are usually performed as second.

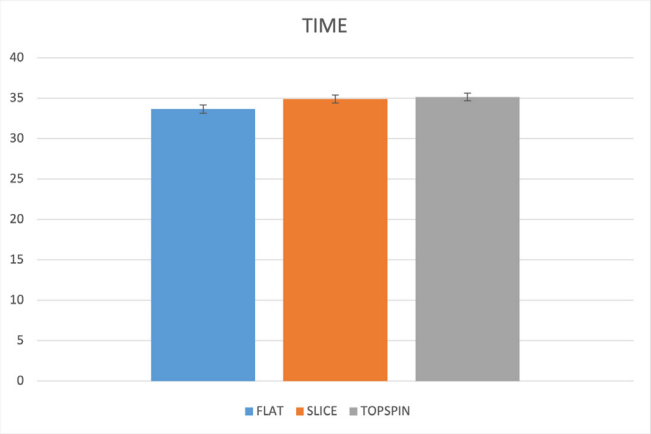

Figure 1. Time from the maximum bending of the knees to the point of contact with the ball, in young athletes (n = 12).

Knee extension, which is a sequence of their maximum flexion, is one of the most important movements in performing tennis service (Elliot et al., 1995). This can increase the speed of the leg extension through the use of stored energy and help move the lower limbs to lead the player towards the ball (Girard et al., 2005).

Comparing the time of young athletes with mean 34.56ms with the time of high level athletes with mean 30.67ms, figure 2, the results showed that the professionals performed the service with much faster and sharper knee extension than the young athletes having a significant difference.

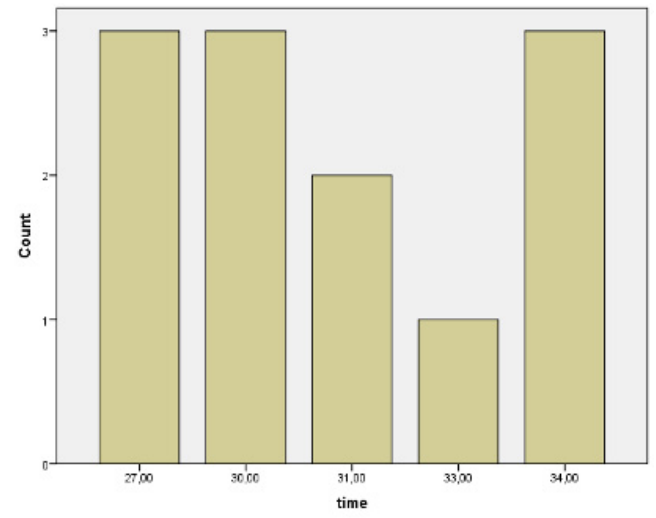

Figure 2. Time from maximum bending of the knees to the point of contact with the ball, in professional athletes (n = 12).

Due to the large degree of extension of the knees in a minimum of time, it is logical that high speeds of movement of the joints are created. Thus, the lack of strong knee extension after the phase of maximum knee flexion would reduce the speed of the racket and therefore the speed of the ball after contact (Reid et al., 2008). Therefore, the increase in knee extension speed seems to be very important in the early stages of development of tennis athletes, so that the pace of service movement is automated and with the development of young athletes more burdens and pressures are added with in order to increase the efficiency of the service, but also to facilitate the transfer of forces from the ground to the contact hand, thus increasing the speed of movement.

From a training point of view, a quick movement of the legs from an angle of inclination to the knees of 90-110° and then with the maximum extent reaching the contact with the ball, is defined as a good practice according to the findings of (Elliot & Reid, 2004). An increasingly intense movement of the legs causes the upper end of the racket to rotate faster, leading to a greater displacement towards the ground (Elliot et al., 1986; Reid et al., 2008). This in turn improves the possibility of higher impact velocities, as although the racket moves away from the ball, the increased storage of elastic energy in the internal turns of the shoulder allows for greater acceleration and leads to contact (Elliot et al., 1986, Roetert & Groppel, 2001; Reid et al., 2008). Thus, the lack of strong knee extension after the counter-movement phase would reduce the speed of the racket and therefore the speed of the ball after its impact (Reid et al., 2008).

PROPOSALS

In the present study, differences were found in the three different types of service, which means that young athletes, in attempting to spin the ball and particular in slice and topspin serves used as second serves, they should have more knee flexion than flat service.

So young athletes will have to constantly improve their coordination of movement until they reach the point of contact with the ball. This means that the time required to perform the phase from bending the knees to the point of contact will be reduced. So the faster the movement is performed after the knee flexion, the more efficient the service will be.

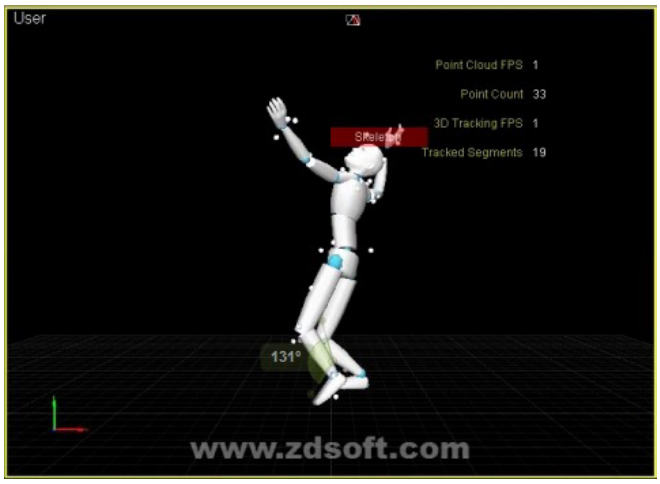

Figure 3. Digital representation of maximal knee flexion when performing flat service.

Figure 4. Digital representation of maximal knee flexion when performing topspin service.

Figure 5. The maximum bending of the knees.

Figure 6. The point of contact with the ball.

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COACHING & SPORT SCIENCE REVIEW

International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 28-30.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.53

Innovation in tennis: An overview of research

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ABSTRACT

During the last decades the tennis ecosystem has been immersed in a gradual process of globalisation, professionalisation and commercialisation in an attempt to effectively respond to the increasing challenges of a rapidly evolving environment. This process has seen a number of innovations being applied in the sport. The purpose of this paper is to provide an overview of some of these practices as covered by both researchers and practitioners. It is concluded that research has mainly focused on technological innovations of tennis products created to increase the experience of the players. It is suggested that further studies should investigate service, policy and administrative innovations in the game.

Key words: change, evolution, progress, technology

Received: 10 January 2021

Acepted: 15 February 2021

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INTRODUCTION

Sport in general and tennis in particular have widely used the term innovation as other areas in society such as arts, culture and health have. Innovation has been understood and defined as a chaotic, complex, iterative and social process that implies the adoption of new practices, structures, or technologies (Wolfe, 1994). As Ratten (2016) indicated, when a given sport is committed to develop ideas with the goal of implementing innovative practices, it can be said that it has an innovation strategy.

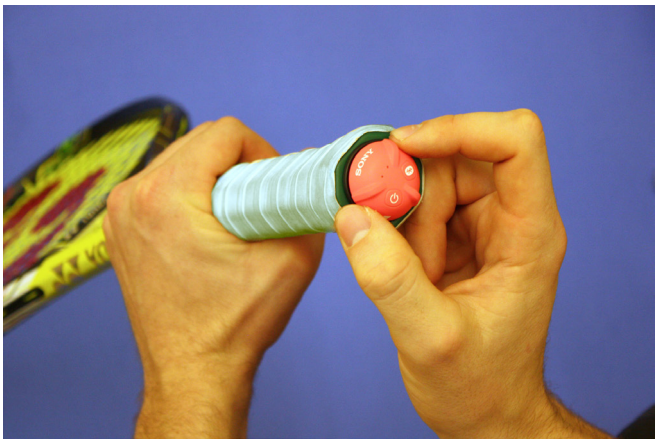
Tennis is a multifaceted activity that can be considered a global industry and a business with many ramifications. A truly lifetime and gender-equal sport which is played in 210 countries worldwide by over 87 million players from all ages, skill levels, abilities and conditions, it attracts more than 1 billion fans and can be considered one of the most popular sports (ITF, 2019).

Authors such as Crespo & Jabaloyes (2020) have highlighted that the wide and strong presence of our game in society drives the sport to adapt, evolve, change and innovate to match the expectations from stakeholders and all those interested.

During the last decades the tennis ecosystem has been immersed in a gradual process of globalisation, professionalisation and commercialisation in an attempt to effectively respond to the increasing challenges of a rapidly evolving environment. This process has seen a number of innovations being applied in the sport. The purpose of this paper is to provide an overview of some of these practices as covered by both researchers and practitioners.

INNOVATION IN TENNIS

As stated by Garcia del Barrio and Pujol (2015), the tennis industry is one of the most significant providers within the



entertainment business. The talent of its top players, the interest of the fans and the number of the playing population are some of the factors the tennis market builds on.

There are special characteristics of tennis such as the need of a given equipment to practice, (i.e., rackets and balls), the unique role of the coaches in the delivery of the sport, and the special features of its competition structure, among other factors, that are considered particularly interesting from an innovation perspective. Therefore, it can be said that, for innovative processes, tennis is especially seen as a favourable scenario.

This phenomenon has been originated from a variety of sources. The firms in the tennis industry have introduced new products and services that have addressed not only the supply side of their industry, but also its demand (Kim and Pennings, 2009). The different tennis organisations have also generated innovative changes in their quest to govern the different areas of the game. The coaches, as the ones who deliver the game at its various levels of practice, are constantly

producing innovations to improve the tennis experience for the players. The media have transformed the diffusion of the sport towards new levels of sophistication. The players, fans, tournaments and other stakeholders have also favoured considerable innovative changes geared to adapt the game to their needs and expectations.

Innovations in tennis have adopted different forms in terms of products, services, technologies and policies, among others. Several studies have investigated the role, implications and impact of the different types of innovations generated in the game.

In the case of product innovations, authors such as Kim and Pennings (2009) have pointed out that the diffusion and imitation of different product innovations by competing organisations and firms in the tennis industry seem to be largely driven by the legitimacy gained of product endorsements by top professionals and advertising. One aspect which has been studied has been the tennis wear creation (Chae, 2017).

As per service innovation in tennis, the provision of statistical services to players and federations, has been studied by Kovalchik and Reid (2019) who stressed how partnerships can generate new insights to help progress the sport. Tennis organisations such as federations and clubs at different levels are also offering innovative services to their members.

In this scenario, the tennis market is drastically being transformed by technological progress, which has provided access to the game to large numbers of new "consumers of leisure" by using the development of mass media. Studies have also investigated aspects such as sales and marketing in the early introduction of the game (Luitzen, Bollerman, and Delheye, 2015) and training methods in tennis (Ren, 2018). Technical innovations in tennis which have been implemented by the manufacturing industry have received considerable interest from researchers since they put technology to good use in the game. Studies in tennis include, among others the spaghetti strings and the composite rackets as cases of technological innovations than often change the nature of a sport (Gelberg, 1996), or officiating (Hawk-Eye Innovations, 2007; Collins & Evans, 2008; Mather, 2008; Singh & Dureja, 2012). Other research about this type of innovations is related to the racquet industry (Kim and Pennings, 2009), the key innovators such as Howard Head (Laudone, Liguori, Muldoon and Bendickson, 2015) or the adapted equipment (Cooke & Davey, 2007; Buszard, Farrow, Reid & Masters, 2014) and its influence on game results (Sheridan, 2006).

As per policy innovations in tennis, they have also been studied in the case of the tennis seeding (Sheridan, 2007) or by analysing the views of coaches on the ITF Play & Stay Campaign as a specific innovative programme (Buszard, Oppicci, Westerbeek & Farrow, 2020).

Interestingly enough, despite many innovations have been generated by tennis organisations in different areas of the game (i.e., the change of the Davis Cup format, the new naming and branding of the Fed Cup to the Billie Jean King Cup by the ITF, or the creation of the Next Gen event by the ATP), no studies have been found that investigate these changes.

In some cases, innovation in tennis has generated controversy and uncertainty in the market (i.e., innovation in racket materials and design). The potential benefits of some new products or services (i.e., the slower tennis balls) may cause doubts as they could provoke technical uncertainty and uncertainty about the existence of a market for the innovations. This scenario can occur no matter if the innovations are radical, incremental or continuous and its characteristics help to better understand successes and failures of innovations in tennis (Buszard, Farrow, Reid and Masters, 2014).

CONCLUSION

The summary of research and initiatives described in the previous section allows to conclude that the sport of tennis has seen a continuous process of renewal. As emphasized by authors such as Kim & Pennings (2009) innovation, apart from the development, production, and launch of new products, it also includes the communication between the organisations or firms and the market.

This study has shown that the tennis ecosystem is implementing different innovations involving a range of resources in order to fulfill the needs and expectations of its stakeholders. In general, this wide variety of initiatives are geared towards increasing participation and fans, improving the performance of the players and providing a better user experience. Many, if not all, of the products and services involve some sort of technological innovation. Some of these innovative practices have received considerable attention from research in an attempt to better understand the key aspects that describe this process.

Research has mainly focused on technological innovations of tennis products created to increase the experience of the players. Therefore, it seems obvious that further studies should investigate service, policy and administrative innovations in the game.

Many of the products or services mentioned offer a unique blend of innovation, experience and accuracy that have revolutionised the tennis world since they are for the betterment of the game. Therefore, it is hoped that tennis will continue to innovate to keep its popularity worldwide.

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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International Tennis Federation
COACHING & SPORT SCIENCE REVIEW
International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 31-34.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.54

Warm-up exercises based on variability

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ABSTRACT

The proper structuring of the content to be developed in a tennis session is one of its most important aspects. Within this structure, the warm-up is a part that should always be present. Despite its importance, on many occasions, the warm-up does not receive from the coaches all the attention it should. The present article proposes a number of methodological tools based on variability training principles with the aim of providing greater specificity and quality to the tennis warm-up.

Key words: warm-up, variability, problem solving

Received: 25 January 2021

Acepted: 30 March 2021

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INTRODUCTION

The correct structuring of the session is a key factor for its success. Several authors indicate that it should follow a logical structure in terms of intensity, starting with some prior exercises in preparation for the main part, in the which the objectives set will be carried out through the relevant content (Devís and Peiró, 1992; Delgado et al., 1999; Serra, 1996). Despite its valuable benefits, the warm-up is often underestimated by both coaches and players, minimizing its importance for the incorporation of different work content.

On the other hand, tennis is an open skill sport, as it is subject to changing stimuli from the environment. Therefore, the learning process of the student should be adapted so that a greater number of stimuli is introduced. This variety of stimuli would permit the player to adapt in a more efficient way to problematic situations that the game will introduce (Sanz et al., 2012). Therefore, tennis training should be varied, changeable and random to produce deeper learning and greater transfer of skills to the real game (Reid et al., 2007; Schmidt et al., 2008).

VARIABILITY LINKED TO WARM-UP

Variability is an intrinsic component of all biological systems, since it is a functional element that facilitates learning and internalising new coordinative structures. In addition, it provides flexibility to the neuromotor system facilitating the learning of new patterns (Araujo et al., 2006). With regard to tennis training specifically, the variable practice or variability in training refers to the process of creating situations that generate an imbalance in the execution. This forces players to spontaneously find new individual movement patterns adapted to the conditions. These new patterns will allow them to increase their motor efficiency (Sanz, Fernández, Zierof, & Mendez, 2012).

One of the most important principles that all warm-up must comply with is that of specificity. This principle refers to the need for activities during warm-up to consider the characteristics of sport in intensity, structures involved or coordination capacities (Unierzynski, Boguslawski, & Wheatley, 2018). Therefore, variability training can be an ideal tool to increase the specificity of the warm-up and facilitate the desired adaptations to occur, not only at a physiological level but also at a neuronal and psychological level (Sanz & Hernández, 2013).

Next, a proposal of warm-up exercises based on variability training with different specific objectives is presented. The objective of this proposal is merely to exemplify a series of examples that can serve as inspiration for coaches to create their own, based on their objectives and the characteristics of their players.

PROPOSAL OF WARM-UP EXERCISES

Mobility

Exercise 1: Both players rally in the service boxes, after hitting the ball they must touch the line marked in front of them with one of their feet and return to their starting position (Figure 1).

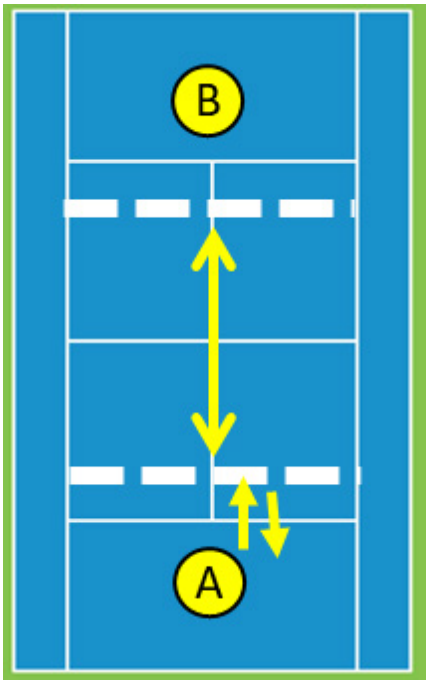

Figure 1.

Exercise 2: Both players rally in the service boxes, after hitting the ball they must touch with one of the feet behind the cone and return to their starting position (Figure 2).

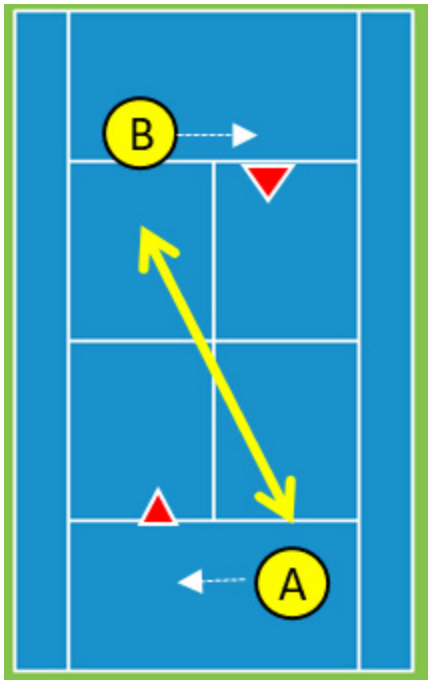

Figure 2.

Exercise 3: Both players rally in squares from s to which, after hitting the ball, they must recover from behind the cone located at the "T" (Figure 3).

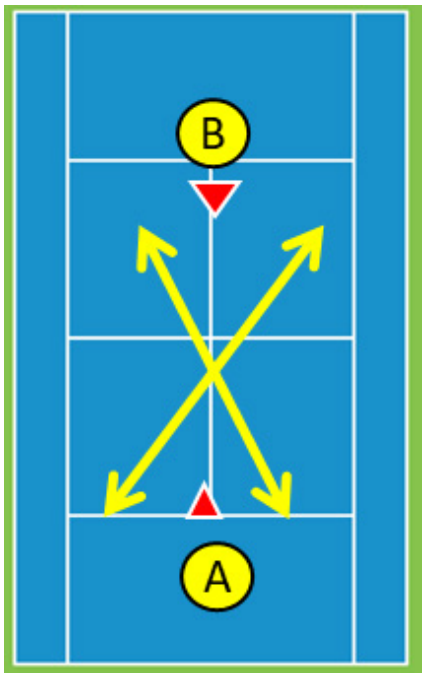

Figure 3.

Control / precision:

Exercise 4: Both players rally in the service boxes trying to keep the ball in play a certain number of times (for example 15). Once they have met this goal, they switch to another ball with a different pressure level (Figure 4).

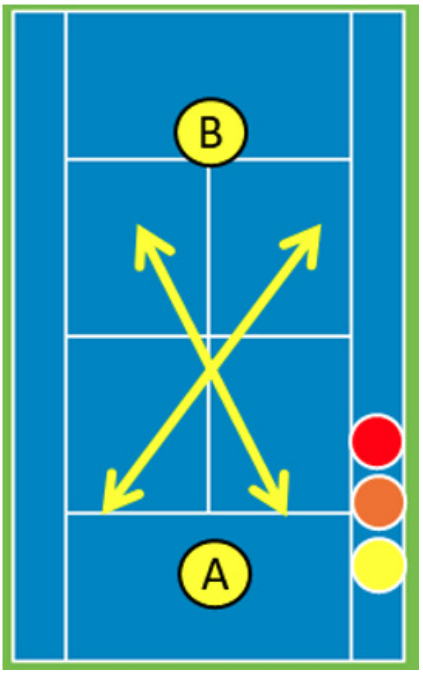

Figure 4.

Exercise 5: Both players rally in the service boxes trying to keep the ball in play a certain number of times within the defined spaces. As a progression, players can be asked to try to alternate three speeds (1,2,3) in the intensity of hitting the ball (Figure 5).

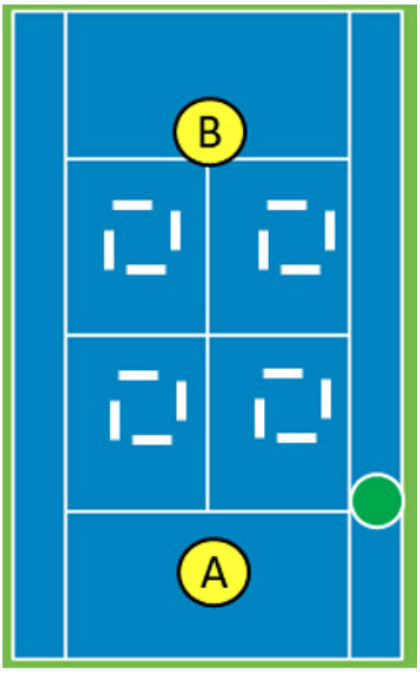

Figure 5.

Concentration:

Exercise 6: Both players rally trying to knock down the cone of the opposite field located in certain areas, each time a player turns a cone he adds a certain score (Figure 6).

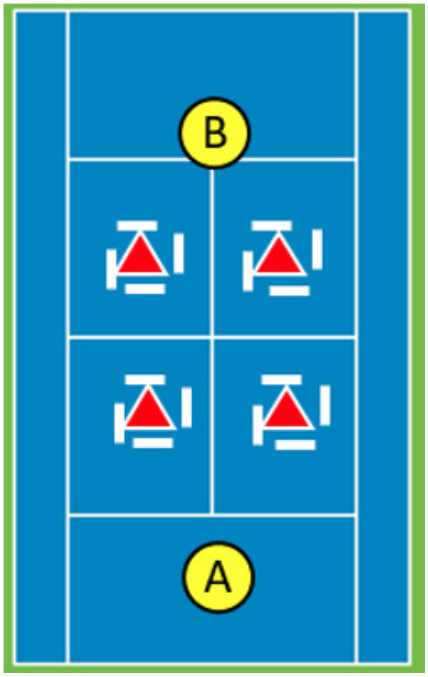

Figure 6.

Exercise 7: Both players rally in a certain direction, trying to play the ball between the cones defined in the opposite field (Figure 7).

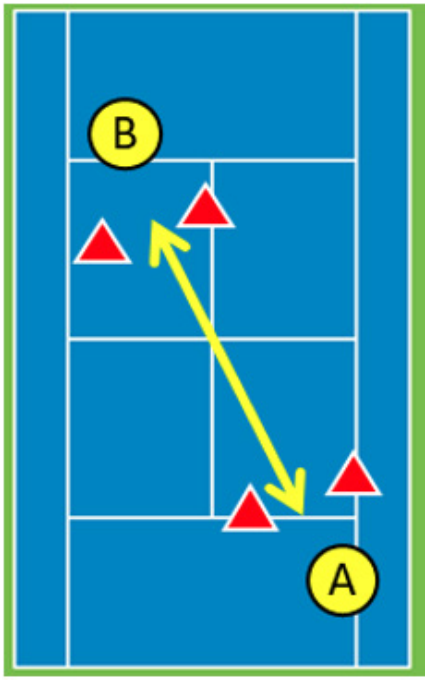

Figure 7.

Exercise 8: Both players rally in a certain direction, both start with an initial score of 10, each time the ball bounces in the + zone they add 1 point, each time it bounces in the - zone they subtract one point. The objective is for the players to achieve the maximum number of points possible while rallying and adding together (Figure 8).

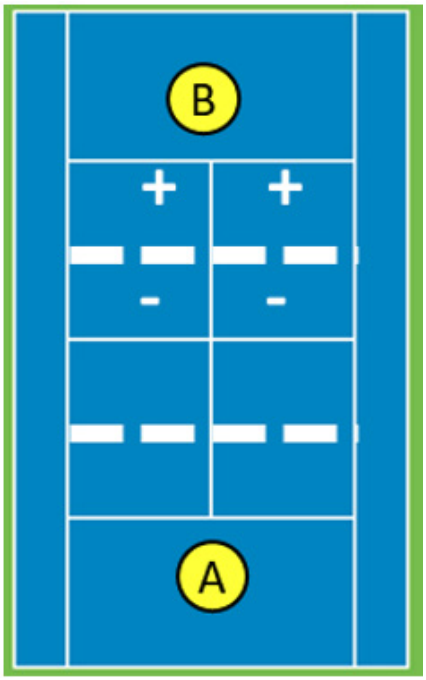

Figure 8.

Explanatory note: All exercises can be adapted to the skill level of the players. The area of the court where the drills are performed can also be modified, in this example the graphs show the drills in the service square, but they can also be done from three quarters or back of the court.

CONCLUSIONS

As it can be seen, the use of exercises based on variability within the warm-up can favour its specificity and facilitate the fulfilment of both physiological and psychological objectives. In addition, these exercises provide a great amount of problem situations that the player must solve, which will allow to acquire a wider repertoire of tools when responding to demands that are present in the different game situations.

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International Tennis Federation
www.itfcoachingreview.com
April 2021. 29th Year. Issue 83. 35-37.
ISSN 2225-4757
https://doi.org/10.52383/itfcoaching.v29i83.55

Determinant physical factors in the wheelchair tennis player

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ABSTRACT

The objective of this research was to identify the most determining physical factors in the ranking position of wheelchair tennis players (WT). In a national camp, the nine best nationally ranked Spanish male WT players (38.35 ± 11.28 years, 63.77 ± 7.01 kg. weight) completed a test battery. Significantly higher correlations were observed in medicine ball throws, 5 and 20-metres sprints with racquet and in an agility test without racquet. In addition, the regression analysis identified two predictor models of the player's ranking position that included both the serve throw and the 5-metre racquet sprint. In conclusion, it is recommended that coaches and physical trainers include in their training programmes medicine ball exercises as well as acceleration drills over short distances.

Key words: tennis, performance, biomechanics, physical tests

Received: 23 January 2021

Acepted: 15 March 2021

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INTRODUCTION

Wheelchair tennis (WT) has achieved the professionalization of the best players in the international ranking (Sánchez-Pay, 2019). This has been possible due to the fact that, in recent years, there has been an increase in the revenue through the prize money distributed in tournaments worldwide, as well as a growth in the companies interested in sponsoring players. No doubt that the presence of WT in the four Grand Slam has facilitated such professional growth. It is therefore vitally important for players to maintain the highest position possible in the ranking, although the information that identifies the most determinant variables for performance is still very scarce.

There are studies that show the differences between winners and losers based on match statistics (Sánchez-Pay, Torres-Luque, Cabello Manrique, Sanz-Rivas, & Palao, 2015), physiological parameters (Sindall et al., 2013), as well as speeds and distances during a match (Mason, van der Slikke, Hutchinson, & Goosey-Tolfrey, 2020). However, there is no related information on the physical parameters of the athlete that better identify the ranking of the players. Therefore, the aim of this paper is to analyse the relationship of the fitness level of WT players and its relation with their position in the ranking.

METHOD

Participants

The sample consisted of the nine best male wheelchair tennis players in the Spanish national ranking (38.35 ± 11.28 years, 63.77 ± 7.01 kg. weight). All of them played in the Open category and took part in national and international competitions. They were or had been among the top 150 in the international ranking.

Procedure

During a national camp, the players carried out a battery of tests distributed as follows: Day 1; Speed test (5, 10 and 20 m.), agility test (T-test), service speed test, and medicine ball throw test (forehand, backhand and serve). Day 2: incremental resistance test (Hit and Turn Tennis Test) and manual dynamometry. All tests were conducted on an indoor hard court. The characteristics of each of the tests were:

- Displacement speed test: The time to travel a distance of 20 metres with doors located at 0, 5, 10, and 20 m. was measured. The players performed the test with and without a racquet three times each.
- Agility test (T-Test). The time to perform the agility test consisting of accelerations and decelerations, as well as turns for both sides, was measured. Each participant performed the test three times without a racquet, and three times with a racquet, with a 2 min. rest time between each repetition.
- Service speed: The average service speed of 10 serves was measured and recorded using a radar gun. The radar was positioned behind the player at the same hitting height and oriented in the same direction as the ball.
- Medicine ball throw: Explosive force was evaluated through three 2 kg medicine ball throw tests, simulating forehand, backhand and serve shots. The players had to throw the ball simulating the technical gesture of the backhand and forehand (on each side with two hands) and the serve (with one hand from the loading position).

- Manual dynamometry: The maximum isometric force in the flexors of the fingers was measured using a manual dynamometer. The best value of three attempts was recorded in N · kg-1.
- Incremental resistance test (Hit and Turn Tennis Test): An adaptation of the test proposed by Ferrauti, Kinner, and Fernández-Fernández (2011) was carried out. The only difference was that the shots had to be performed on top of a cone located at the intersection of the singles line with the bottom line, coinciding with the sound signals emitted by a CD.

Statistical analysis

The Shapiro-Wilk and Levene tests were used to contrast the normality and homogeneity of variances for each variable. A Spearman correlation analysis was performed to identify those variables related to the ranking position. Subsequently, a stepwise linear regression analysis was performed to identify the parameters with the greatest influence on the ranking position. The significance was established at $p < 0.05$. All data were analysed with the IBM SPSS 25.0 statistical package for Macintosh (Armonk, NY: IBM Corp).

RESULTS

Table 1 shows the correlation coefficients of the different physical tests with the player ranking. The higher statistically correlation was observed in the medicine ball serve throw ($r = -0.995$), showing a negative correlation. The 5 to 20 metre tests with racquet, and T-test without racquet showed the highest positive correlations ($r = 0.817$, $r = 0.833$ and $r = 0.817$ respectively).

Table 1

Correlation coefficient of the physical tests with the ranking position.

Test	r	p
Dyna. Dom (kg)	-0.247	0.522
Dyna. Non-Dom (kg)	-0.150	0.708
Spe. Serve (km h -1)	-0.767	0.021
5m without racquet (s)	0.783	0.017
10m without racquet (s)	0.783	0.017
20m without racquet (s)	0.717	0.037
5m with racquet (s)	0.817	0.011
10m with racquet (s)	0.383	0.313
20m with racquet (s)	0.833	0.008
T-Test without racquet (s)	0.817	0.011
T-Test with racquet (s)	0.783	0.017
Ball throw F (m)	-0.733	0.031
Ball throw B (m)	-0,700	0.043
Ball throw S (m)	- 0.995	<0.001
Hit and Turn	-0.778	0.014

Table 2 shows the results of the multiple regression analysis. The analysis mainly identified two models. The first model showed the medicine ball throw simulating a serve as the main predictive measure of the player's ranking ($r^2 = 0.830$, $p < 0.001$). The second model showed the medicine ball throw simulating a serve and the 5-metre sprint with the racquet as the two predictive variables in the player's ranking ($r^2 = 0.929$, $p < 0.001$).

Table 2

Multiple regression statistical analysis.

	R	R^2	R^2 adjusted	F	Sig F.
Model 1	0.911	0.830	0.806 Beta	34.193 T	< 0.001 Sig T.
Ball Throw S (m)			- 0.911	-0.911	<0.001
	R	R^2	R^2 adjusted	F	Sig F.
Model 2	0.964	0.929	0.905 Beta	39.239 T	<0.001 Sig T.
Ball Throw S (m)			- 0.641	-4.463	0.004
5m with racquet (s)			0.415	2.890	0.028

The relationship between the medicine ball throwing tests simulating a serve and the 5-metre sprint with a racquet is observed in Figures 1 and 2. The throw test maintains a negative relationship, since as the player's ranking moves away from the first place (greater numerical value), the distance of the throw decreases. On the contrary, in the 5-metre sprint the relationship is positive, since as the player's ranking is higher (lower numerical value), the time to cover the 5 metres decreases.

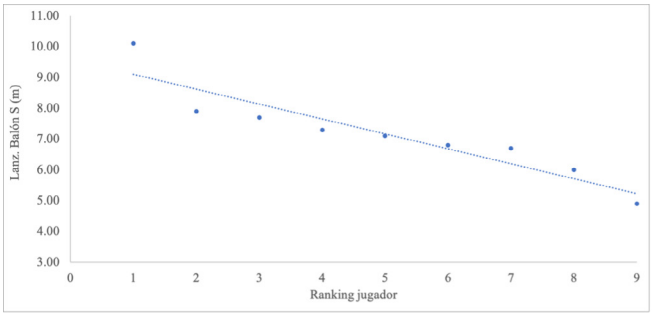

Figure 1. Relationship between the medicine ball throw test simulating a serve (m) and the player's ranking. Figure 2. Relationship between the 5-metre sprint with a racquet and the player's position in the ranking.

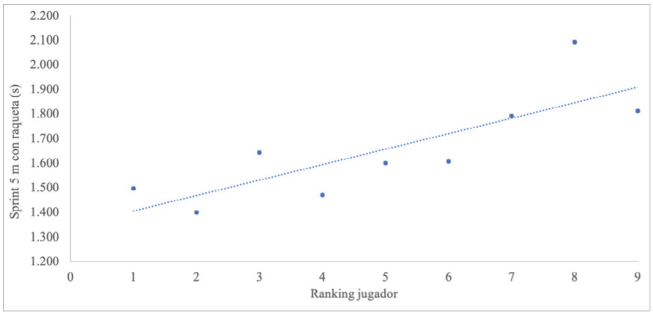

Figure 2. Relationship between the 5-metre sprint with a racquet and the player's position in the ranking.

DISCUSSION

Knowing how physical demands relate to each other and identifying which are the variables that determine performance, can provide coaches with important and specific information for the design of exercises tailored to the needs of the sport. The objective of this research was to know the relationship of different physical demands evaluated through field tests with the ranking position of WT players. In general, it is observed that the vast majority of the measurements carried out showed a relationship with the ranking position of the players, although only the medicine ball throw simulating a serve and the 5-metre sprint with a racquet were shown as the predictive variables.

The medicine ball throw was shown as the main predictive measure of the player's ranking position (table 2). Given the similarity in the mechanics of throwing with the service technique, this test could have a direct relationship with service speed, which is known to be a good performance indicator in standing tennis (Brown & O ' Donoghue, 2008) and is related to some parameters of the physical condition of tennis players (Fett, Ulbricht, & Ferrauti, 2020). However, this is a hypothesis that needs to be tested in future studies.

The 5-metre racquet sprint was shown as a predictor variable of the player's ranking position (table 2). Therefore, a shorter acceleration time in the first 5 metres seems to be a good performance indicator. A good mobility in competitive WT is essential (Bullock & Pluim, 2003), since it allows the player to hit more shots with success (Filipcic & Filipcic, 2009). These movements are intermittent and multidirectional, which challenges the player to use specific movements such as accelerating, sprinting, braking, and turning the wheelchair (Roy, Menear, Schmid, Hunter, & Malone, 2006; Sanz, 2003). The fact that the 5-metres sprint is shown as a predictor of performance, stresses the importance of accelerating versus achieving high speeds (Vanlandewijck, Theisen, & Daly, 2001), where the propulsion most effective is when the maximum possible speed is achieved in the least number of pushes to the chair (Goosey-Tolfrey & Moss, 2005).

CONCLUSIONS

The medicine ball toss simulating the serve, and the 5-metre sprint were shown as the variables that best predicted the ranking position of WT players. Therefore, coaches and physical trainers are encouraged to include the medicine ball throw as a transfer exercise to the technical gesture of serving within their training programmes. In the same way, a specific work of acceleration with the chair is necessary in the first metres, paying special attention to the individual biomechanics of the gesture, since the functional limitation of each athlete will determine to a greater or lesser extent the impulse technique on the chair hoops.

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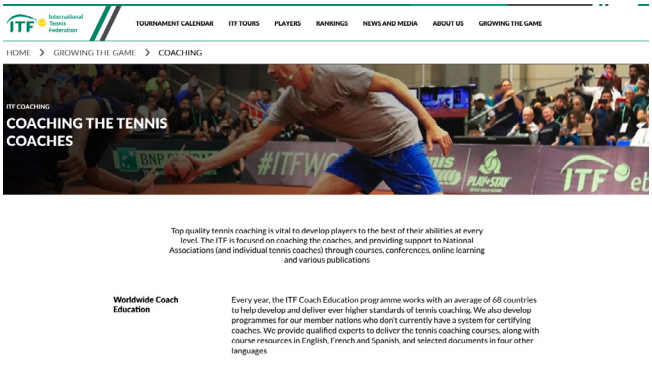

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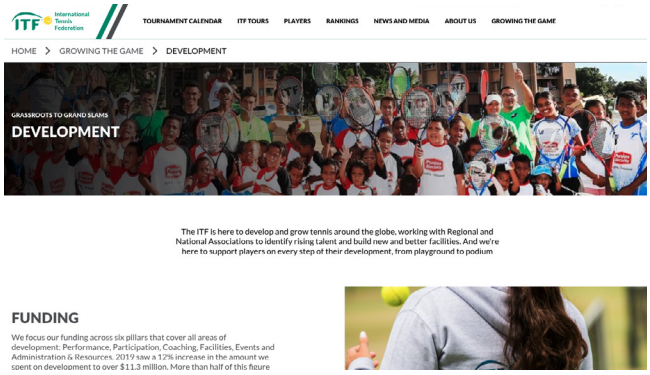

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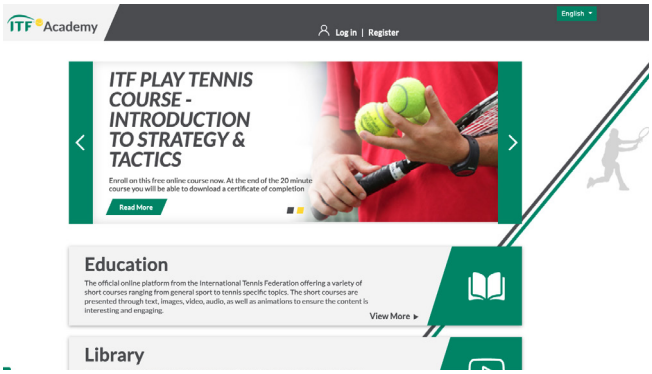

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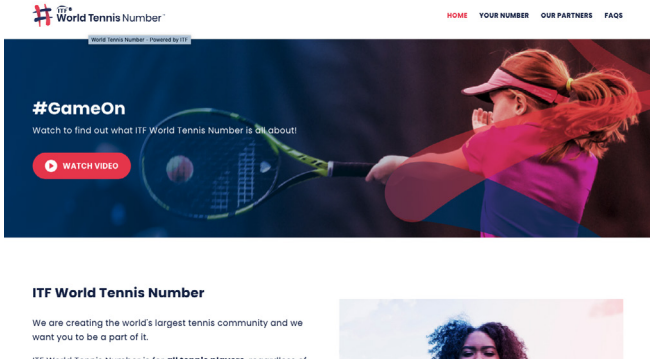

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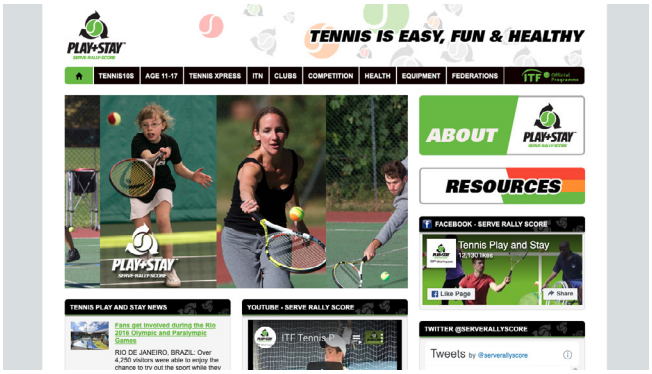

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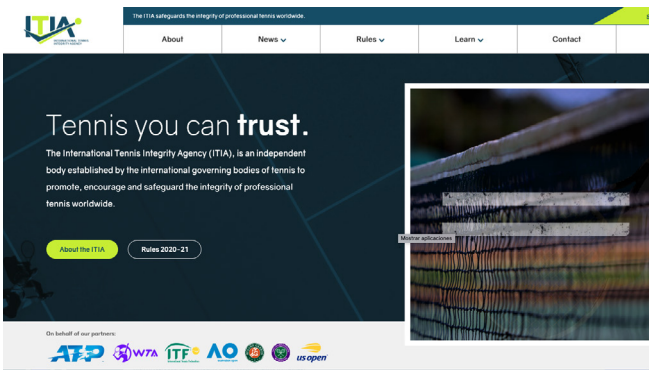

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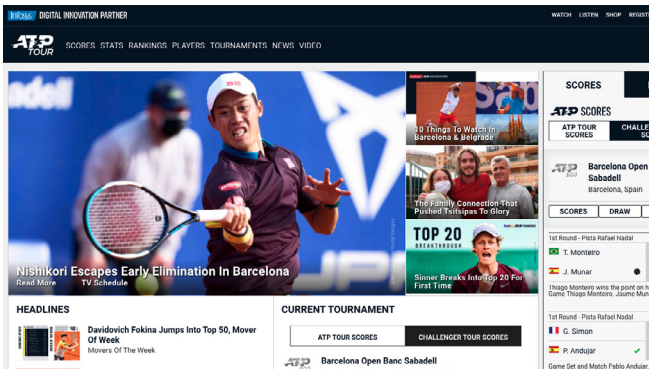

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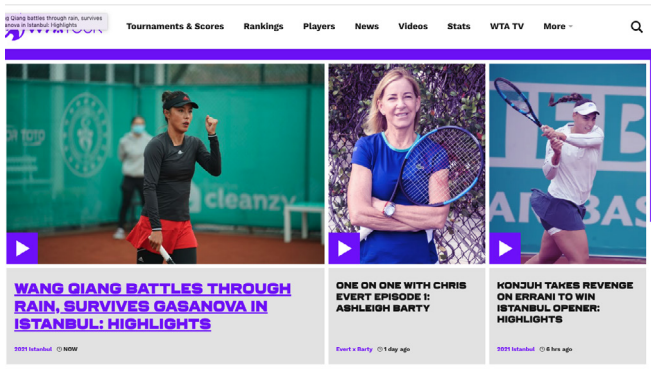

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