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Editorial

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Welcome to issue 88 of the ITF Coaching and Sport Science Review. This issue is the last one of 2022. It is available in the ITF Academy as well as in the new page of the journal, which can be accessed here. This issue covers an interesting variety of topics which include stroke footwork, serve performance, hydration, incidence of injuries, feedback and learning, improvement of reaction time, test to assess displacements, performance narrative, quantification of training load, and a sport science evidence-based approach to coaching.

Within the 2021-2024 ITF development strategy the Education pillar includes several projects that have been implemented throughout 2022. ITF supported 32 certification courses organised by 30 National Associations, from August to December 2022.The in-person courses followed the standard ITF syllabi for ITF Play Tennis, Coaching Beginner and Intermediate Players, Coaching Advanced Players, and Coaching High-Performance Players courses. Fifteen courses were funded by Olympic Solidarity (OS) of which six were Regional Technical Courses for Coaches, with different type courses taking place in Cambodia, Lithuania, Mexico, South Africa, and Tunisia.

Three ITF Regional Coaches Conferences (RCC) took place during the second half of the year. In person conferences were held in Bali, Indonesia from 27 to 29 October (English speaking conference) which was attended by 161 coaches representing 36 nations, and Bogota, Colombia from 1 to 3 November (Spanish speaking conference with English translation) with 177 coaches attending representing 31 nations. A two-day virtual French speaking conference was delivered through the ITF Academy on 20 and 21 October and attended by 142 coaches representing 29 nations. Therefore, a total of 480 coaches from 96 nations took part in these Conferences.

Two types of courses were offered as part of this year's OS Scholarship programme for coaches in Valencia – the ITF Coaching High-Performance Players course and the ITF Coaching Advanced Players (CAP) course for former players. All the courses were completed, with former players Marcos Baghdatis (CYP), Karolina Sprem (CRO) and Alexandra Dulgheru (ROM) completing the CAP course. All nine former players, coaches of national teams who attended the practical part of the course passed. The theoretical parts of the courses were delivered through the ITF Academy. The 28 selected candidates completed either the four or six-week theoretical part of their respective courses at the end of May/mid-June, while the practical aspects of the certification courses took place in July and August. It is great to see former professional players moving to the coaching pathway reinforcing the message that tennis is everyone's game.

The ITF is providing opportunities for those interested in getting involved in tennis at all levels of the game through a financially sustainable educational platform, which is a win-win situation for member nations, regional associations, users, and the ITF. The ITF Academy is one of our key digital assets. Subscriptions for the platform soared during the pandemic, and this doesn't appear to be slowing down as we saw a 20% increase in registered users this year. The ITF Academy is a bespoke learning management system used to deliver information, education and certification opportunities to national associations, coaches, players, parents, fans, and administrators, which is available in 11 languages.

More courses were added to the growing library of content this year so that users can learn about the ITF World Tennis Number, Beach Tennis, Physical literacy, and High-Performance Sport for Athletes with an intellectual impairment, among others. Looking ahead to 2023 and based on feedback obtained from National Associations and other stakeholders, we will be launching a programme for club managers, a new Officiating section, a course on coaching Female Players and a series of courses on Wheelchair Tennis. By continuously adding new and varied content relevant to the users, the ITF Academy aligns with the ITF strategy to service different audiences and interests for the benefit of the game.

ITF Data Sharing Agreements (DSAs) have been sent to 99 NAs who agreed to an ITF Academy NA package, of which 85 have activated their packages and are actively using the platform to host national certification courses and education workshops or webinars. At the time of writing, the ITF Academy has more than 56,500 registered users and 199,000 anonymous users who have access to more than 190 English courses, 154 French courses, 147 Spanish courses, 151 courses in Portuguese, 159 courses in Russian, 99 in Arabic, 59 in Indonesian, 66 in Chinese, 33 in Turkish and 19 in Slovak the most recently added language. Persian will be the next language to be launched. For the period 1 July 2022 to 11 December 2022, more than 1,000,000 (one million) page-views were recorded, with users spending an average of 21 minutes per session, browsing an average of 17 pages. Library (former iCoach) content has also increased from 1,400 in 2021 to more than 1,650 to date.

The new ITF eBooks Progressive Web App (PWA) launched in August and is hosted within the ITF Academy. Users of the existing eBooks app received notifications through both the old and new app with details on how to migrate their current titles to the new platform. Currently all ITF course manuals are available on the new eBooks app as the existing content continues to be uploaded to the new platform. The ITF Advanced Coaches Manual is available for free, can be accessed and downloaded from the new app.

The ITF through Advantage All Campaign is facilitating three coaches to take part in the Women in Sport High Performance Pathway (WISH Programme) which has been developed in cooperation with the IOC/Olympic Solidarity, ASOIF, AIOWF and several International Federations already engaged in projects to increase opportunities and pathways for high performance women coaches. The Olympic programme has been developed in coordination with a team of specialists at the University of Hertfordshire to equip female coaches, who have the potential and ambition to succeed in gaining roles at elite coaching levels within their sports. The programme runs over 21 months and allows women who are involved or have the potential to be involved in elite coaching, to access leadership training, leadership mentoring and complementary sport-specific training led by the IF and with the engagements of the National Olympic Committees. The ITF candidates this year are Olha Khaniukova (Ukraine), Radhika Kanitkar (India), and Roxanne Clarke (South Africa). The coaches have attended a residential week in the UK in October and will continue the course next year.

Furthermore, a Development of a National Sport System (DNSS) project in Mauritius concluded at the end of April 2022. Ongoing DNSS projects include Bahrain, eSwatini and Chad with Turkmenistan approved as well. Since its launch last summer, 24 tutors have been recognised through the ITF International Tutor Certification programme. To date, eight nations have had their coach education system recognised by the ITF in 2022 through the Recognition of Coach Education Systems programme. There are now 69 nations in total of which 18 are recognised at Gold, 10 at Silver, 22 at Bronze and 19 at White level.

As part of the Participation pillar for the past 25 years, the ITF Junior Tennis Initiative has been an essential component of the player pathway. The national 14&Under grassroots programme is one of the most successful for introducing tennis across the four corners of the globe and providing the platform for many talented players to progress onto the regional Tours and the ITF Junior World Tennis Tour within their respective countries.

There are 142 active JTI nations currently supported by the ITF with many now utilising a new online reporting platform that has been implemented during 2021 and to provide us with their level of tennis activity. All National JTI Coordinators must complete a specific set of pre-requisite online courses via the ITF Academy, ensuring continuous professional development is available and that a minimum standard of understanding is attained across the programme by the key personnel responsible.

The JTI is not just about putting rackets in children's hands for the first time or finding the most talented players such as Kenyan's Angela Okutoyi and Iran's Meshkatolzahra Safi. It is a programme that provides opportunities for everyone to be involved in the sport, whether you are a deliverer, a parent, a player, or someone engaged in tennis as a fan.

We are seeing many former players who were first introduced to tennis through the JTI, using their knowledge and experience to help grow the next generation of players by taking on other roles in tennis. And then there's the tennis parents, who want to do more to support their wider community. The ITF Parent Education pathway is available through a series of courses and national workshops via the ITF Academy.

Understanding the tennis landscape is crucial to put in place a strategy for long term growth. Last year we published an update to the ITF Global Tennis Report focused on 41 nations who make up 90% of the tennis playing population, courts, and coaches. We are leading the way amongst other International Sport Federations by collating data from our member National Associations and utilising it to support the growth of the game.

This will data collation process will continue in 2023 as we look to further understand the landscape of tennis through this insight across the world. In 2024 we will publish the next ITF Global Tennis Report to position us clearly on our journey to "30 by 30", 30-million more players by 2023.

You will be already aware of the key role of the ITF World Tennis Number (the "WTN") as a new digital product to open up the sport and make it more inclusive by inspiring players of all levels to play more often and stay in the game.

The vision of the WTN is to ensure all National Associations drive participation and act as leaders of their tennis community. To do this we have created a digital and physical community of players with a common language and have made a first-class global rating available to any player in the world.

As of today, 18 member associations and the ITF have publicly and successfully launched to 1.4 million players. And in total 153 Nations have signed up to take part in the project. There are more than 60 member associations securely sharing millions of tennis records which are used to power the sophisticated singles and doubles algorithms.

The Ukrainian Tennis Federation is working with the ITF to provide World Tennis Numbers for those players in the country, providing an opportunity and incentive for them to keep playing tennis, and to be part of a global rating community without the need for travelling. The ITF WTT Juniors and ITF Masters Tours have been using WTN as the acceptance criteria for all their tournaments and World Championships since May. The ITF will continue to successfully roll out the ITF World Tennis Number product and systems with the aim to build a large, engaged community of global players. To find out more about ITF World Tennis Number please visit www.worldtennisnumber.com

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

We would also like to encourage new submissions to the ITF CSSR through the new platform. Finally, we would like to thank all the authors for their contributions, as well as all of those who sent in proposals. Full guidelines for acceptance and publication of articles can be found in the most recent issue page on the ITF Academy. We hope that you enjoy reading the 88th edition of the ITF Coaching and Sport Science Review.

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RECOMMENDED ITF TENNIS ACADEMY CONTENT (CLICK BELOW)

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Distribution of intensities and quantification of training load in young U15 elite tennis players

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ABSTRACT

The objectives of this study were to quantify training intensity as a function of time spent in three metabolic intensity zones, to compare programmed intensity, measured intensity (heart rate) and estimated intensity (RPE: Rating Perceived Exertion), and then to determine the training loads in 8 high level male tennis players. No difference was found between the time programmed in zones 1 (69.9 ± 4.8 %) and 2 (22.8 ± 4.4 %) and the time spent at a heart rate below Ventilatory Threshold 1 (VT1) (78.9 ± 9.4 %) and between VT1 and Ventilatory Threshold 2 (VT2) (18.3 ± 9.5 %) ($p > 0.05$). Thus, they trained in accordance with the programmed and recommended intensity distribution by adopting a "pyramid" pattern of intensity distribution. Furthermore, significant differences were found between the percentages of scheduled time and the percentages of perceived time (RPE) for all zones ($p < 0.05$). The overestimation of the estimated intensity can be explained by their age and the intermittent nature of tennis. Finally, we can note that the programmed training load is like that observed for players of the same age and level.

Key words: intensity distribution, training load, RPE, heart rate.

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INTRODUCTION

In addition to the mental, technical-tactical and perceptive-cognitive qualities that the athlete must possess, tennis performance requires a complex interaction between the energy pathways (aerobic and anaerobic) (Fernandez et al., 2006) and complete physical qualities (speed of movement, endurance, explosive strength, coordination, agility, flexibility) (Girard et al., 2018). The combined development of these different capacities requires methodological skills on the part of the coaches. Several studies have quantified the intensity of training in different types of endurance athletes (Esteve-Lanao et al., 2007; Seiler & Kjerland, 2006). To quantify training intensity, coaches usually rely on physiological and subjective indicators and divide the range of training intensities into 3 or 5 distinct zones. The 3-zone model and the 5-zone model have common intensity points around the lactic (2 and 4 mmol.L-1) and ventilatory thresholds (Seiler, 2010) (Figure 1).

The model most commonly used by athletes, particularly in tennis, is the so-called "polarised" model (Stöggl & Sperlich, 2014). In this model, 75-80% of the sessions are performed at low intensities, i.e. less than or equal to the first ventilatory threshold (Zone 1) and 15-20% at intensities, known as very high, greater than or equal to the second ventilatory threshold (Zone 3) (Laursen, 2010; Stöggl & Sperlich, 2014; Treff et al., 2019). In addition to the distribution of intensities, coaches also seek to achieve a sufficiently high training load while limiting the risk of injury (Halson, 2014). A variety of methods have been proposed to measure training

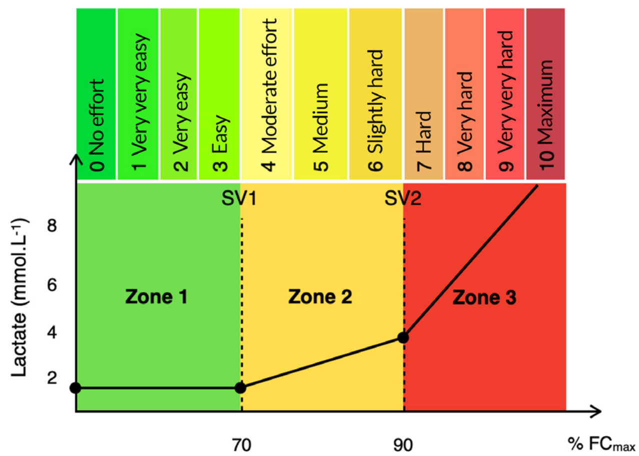

Figure 1. *The three-intensity zone model, including RPE equivalence, based on the identification of lactic and ventilatory thresholds (SV1 and SV2).*

load. The principle common to the various approaches to quantifying training load is to multiply a volume indicator by a difficulty or intensity indicator of the training (Foster et al., 2001; Impellizzeri et al., 2004). They are divided into two approaches: on the one hand, quantification methods based on physiological variables (heart rate (HR), lactatemia, maximum oxygen consumption (VO2max)); on the other hand, methods using psychometric variables (difficulty of perceived effort, called RPE) (Seiler, 2010). Heart rate is a parameter that can be measured quickly, non-invasively, easily implemented in training and applicable to a large number of players at the same time (Buchheit, 2014). In addition, numerous methods for quantifying training load, based on heart rate, have emerged, notably the "Training Impulse" method (TRIMPS) (Banister, 1991 ; Edwards, 1993 ; Lucia et al., 2003). However, the measurement of heart rate as the only tool for analysing training load requires a certain amount of expertise when analysing and interpreting the data collected. Other physiological measures, such as lactate and VO2max measurements, are not practical in training situations and even less so in competition. In order to quantify the training load, RPE is the most frequently used method (Halson, 2014). The RPE, developed by Borg, allows the athlete to provide information about his or her perceived effort after training or competition on a Borg scale (Borg, 1998). Chen et al. (2002) have indicated that the RPE is a valid means of assessing exercise intensity. In addition, the assessment of perceived exertion is widely recognised as one of the most appropriate methods for monitoring tennis load (Coutts et al., 2010 ; Gomes et al., 2011). The method proposed by Foster et al. (2001) called session-RPE (sRPE), consists of multiplying the overall perceived difficulty of the session (RPE taken on a modified Borg CR-10 scale) by the total duration of the session (in minutes) to obtain a score expressed in arbitrary units (AU) that quantifies the training load. However, no published study has described the distribution of training intensity and training loads in high-level U15 tennis players. The main objective of this study was therefore to quantify the distribution of daily training intensity and training loads in young tennis players. We also compared the distribution of training intensity using two independent measures: heart rate and perceived effort during training sessions. We hypothesised that players would train in a 'pyramid' training pattern, where relatively little training would be performed at intensities above the second ventilatory threshold.

MATERIALS AND METHODS

Players

Eight male tennis players (age: 13.8 ± 1.0 years; height: 166.1 ± 12.8 cm; body mass: 51.5 ± 11.0 kg) with an International Tennis Number (ITN) ranging from 2 to 3 (ITN 2 = 2 players; ITN 2 = 6 players) and belonging to the Pôle France (integrated into the CREPS of Poitiers), participated in this study. The recruited tennis players, who were volunteers, were in good health and free of any type of chronic injury. After receiving information about the procedures used in this study, the participants and their legal representatives signed an informed consent form.

Procedures

At the beginning of the season, all players completed the TEST procedure which determined ventilatory thresholds for tennis training (Brechbuhl et al., 2016a, 2016b). Then for 12 weeks (February to May) of the 2022 season, Heart Rate (HR) and Rating of Perceived Exertion (RPE) were collected during training sessions, simulated matches, and official matches. The training programme was planned by the tennis coaches for each player according to the tournaments, the fitness level, possible injuries, and the technical and physical goals of each player. The training sessions took place 70% of the time on outdoor clay, 25% of the time on indoor GreenSet® and 5% of the time on outdoor GreenSet®. Each tennis player performed 11.5 ± 2.2 technical/tactical training sessions per week ranging from 30 minutes to 3 hours in duration for each training period (morning or afternoon). Heart rate data were collected during each training session using a Polar H10 heart rate monitor® (Polar Electro, Kempele, Finland), except for weeks 9 and 10 (Figure 2B), when data could not be collected (International Tournament). In addition, every evening, each athlete recorded their RPE for the whole of each session (morning and/or afternoon) using the modified Borg CR-10 scale (Foster et al., 2001 ; Gomes et al., 2015 ; Haddad et al., 2017). Players were asked to choose a score between 0 (rest) and 10 (maximum effort).

DATA PROCESSING

The distribution of intensity

Training duration was determined using the coaches' planned training schedule. Heart rate data was only considered when the player wore the heart rate monitor at least 75% of the time for each week. This data was recorded using Polar Team System software® (Polar Electro, Kempele, Finland) which calculates the percentage of time spent in each of the predefined HR zones. This data was then used to determine the intensity of each training week in three intensity zones (Zone 1 ≤ SV1; Zone 2 > SV1 and < SV2; Zone 3 ≥ SV2). The two ventilatory thresholds, for tennis training, were established on the basis of the results of the TEST procedure (Brechbuhl et al., 2016a, 2016b). Based on the results of a study of 14-15 year old triathletes with a comparable training volume (Birat et al., s. d.), SV1 was set at 70% HRmax and SV2 was set at 90% HRmax for all non-tennis training for all players. For the RPE data, the CR-10 scores were divided into three zones: Zone 1 ≤ 4; Zone 2 > 4 and < 7; Zone 3 ≥ 7, according to Seiler & Kjerland (2006). Subsequently, the time spent in each RPE zone per week was calculated by summing the duration of each session for each zone. The percentage of time spent in each heart rate-based and RPE-based training zone was compared to the coaches' programmed intensity distribution.

The training load

The results of the Gomes et et al. (2015) study confirm the validity and, therefore, the possibility of using the session-RPE (sRPE) method to quantify training load in tennis. The daily training load or sRPE is calculated as the product of intensity (half-day sRPE) and volume (the duration of the activity) (Foster et al., 2001). Then the weekly training load is obtained by summing the daily sRPEs for the week.

DATA ANALYSIS

All data were expressed as mean ± standard deviation and were analysed using RStudio (RStudio v1.3.1093, US). The normality of the data distribution was checked by the Shapiro-Wilk test. The distribution of training intensity was compared for each assessment method (programmed (trainer) vs. measured (HR) vs. estimated (RPE)) and for each intensity zone (Zone 1 vs. Zone 2 vs. Zone 3) using a two-factor ANOVA (assessment method and intensity zone). If a significant difference was found, a pairwise comparison (Bonferroni method) was used as a post-hoc test. The significance level was set at $p < 0.05$ for all analyses.

RESULTS

On average, each week, the scheduled intensity is distributed as follows: more than 9 h of training in Zone 1, about 3 h in Zone 2 and 1 h in Zone 3 (Figure 2A). The heart rate data show that the players spent on average just under 12 h in Zone 1, just over 2 h in Zone 2 and 30 min in Zone 3 each week (Figure 2B). Regarding the distribution of intensities achieved according to the RPE, the players perceived their effort, on average per week, more than 4 h in Zone 1, about 5 h in Zone 2 and 3 h in Zone 3 (Figure 2C).

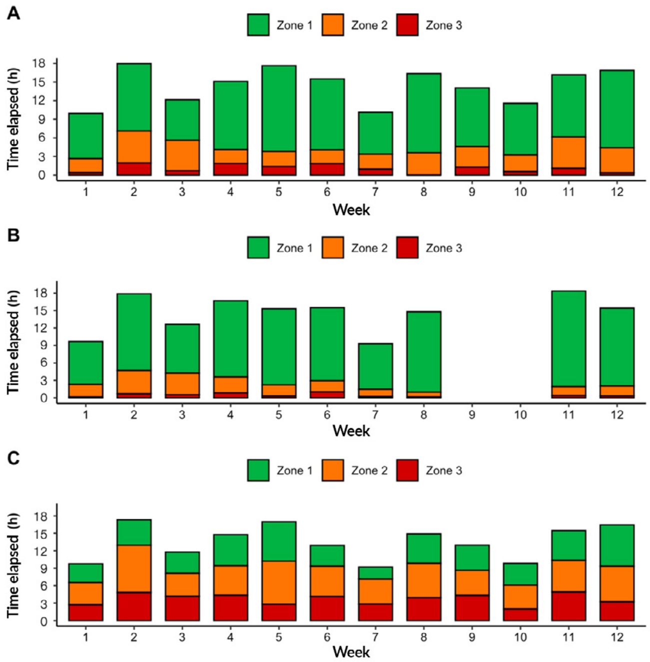

Figure 2. *Average distribution of training intensity (h) for all players over 12 weeks (A: Scheduled intensity, B: Measured intensity and C: Estimated intensity).*

The average percentage of time spent in each of the three intensity zones according to the three assessment methods (programmed (trainer) vs. measured (HR) vs. estimated (RPE)) is presented in Figure 3. Statistical analysis revealed a main effect of the "Zone" factor ($p < 0.05$), no effect of the "Evaluation method" factor and a significant interaction between these two factors ($p < 0.05$). A significant difference was found between the percentage of time scheduled in Zone 1 (69.9 ± 4.8%) and the percentage of time perceived by the players in Zone 1 (Intensity ≤ 4 on the modified Borg CR-10 scale) (36.0 ± 14.0%) ($p < 0.001$). No difference was found between the time scheduled in Zone 1 and the time spent at or below SV1 (78.9 ± 9.4 %) ($p > 0.05$). A significant difference was found between the percentage of time programmed in Zone 2 (22.8 ± 4.4 %) and the percentage of time perceived by the players in Zone 2 (Intensity between 4.5 and 6.5) (38.3 ± 8.1 %) ($p < 0.01$) No difference was found between the time programmed in Zone 2 and the time spent at a heart rate between SV1 and SV2 (18.3 ± 9.5 %) ($p > 0.05$). Furthermore, significant differences were found between the percentage of time programmed in Zone 3 (7.3 ± 2.0 %) and the percentage of time spent at a heart rate greater than or equal to SV2 (2.7 ± 2.0 %) ($p < 0.001$) and that perceived at an intensity ≥ 7 (25.7 ± 12.0 %) ($p < 0.05$).

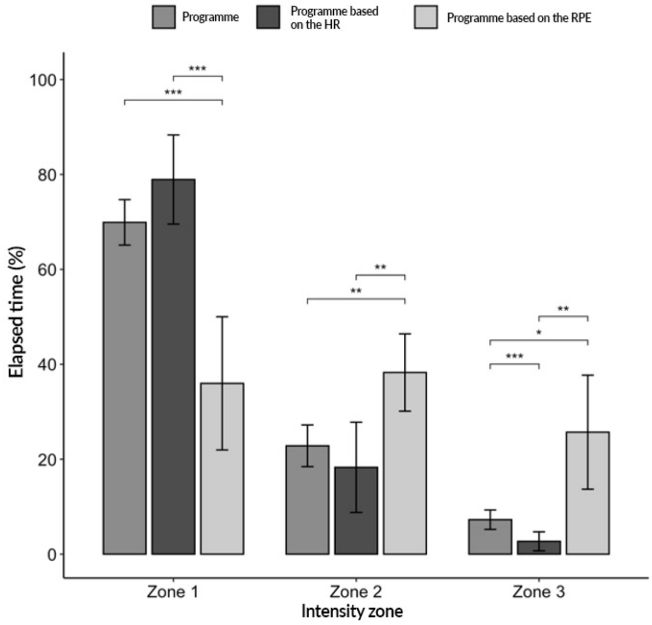

Figure 3. *Average intensity distribution of all players over 12 weeks of training and matches based on two different quantification methods: Measured intensity (Heart Rate) and estimated intensity (RPE). * p < 0.05; ** p < 0.01; *** p < 0.001.*

As the training programme was planned for each player according to tournaments (singles and doubles matches), fitness and injuries, we chose to represent the training load of two players, representative of the inter-individual variability. In total, 18 matches were played with an average win rate of 61.1 ± 15.1 % for player 1 (Figure 4A) and 9 matches were played with an average win rate of 22.2 ± 29.9 % (Figure 4B). The average weekly training load during the 12 weeks was 5445 ± 2016 AU (Arbitrary Units), ranging from 1935 AU to 9375 AU for player no. 1 (Figure 4C) and 4381 ± 1919 AU, ranging from 1950 AU to 7710 AU for player no. 2 (Figure 4D). The training load is well individualised, but it did not have the expected results in terms of winning for player no. 2. Furthermore, we found that there is no higher training load in the training weeks compared to the match weeks.

DISCUSSION

The aim of this study was to quantify the distribution of daily training intensity with different assessment methods, and to follow the evolution of training load in young elite tennis players from programmed intensity revealed that a pyramidal distribution, whereby 70-75% of the total training volume is performed at low intensities (Zone 1) and about 5-10% at very high intensities (Zone 3), is proposed. This distribution has been suggested as one of the optimal training intensity distributions and one of the most frequently used in adult elite endurance athletes (Bourgois et al., 2019; Brechbuhl et al., 2017). The results observed via the heart rate monitor are similar to the training sessions programmed in Zone 1 (78.9 ± 9.4 %) and 2 (18.3 ± 9.5 %). These results are in line with those of the Baiget et et al. (2015) conducted with 20 high-level Spanish tennis players (age: 18.0 ± 1.2 years; gender: male) simulating tennis sets, where players spent on average 77% of the time in Zone 1 (below SV1), 20% in Zone 2 (between SV1 and SV2), and only 3% in Zone 3 (above SV2). As a result, the young male tennis players at

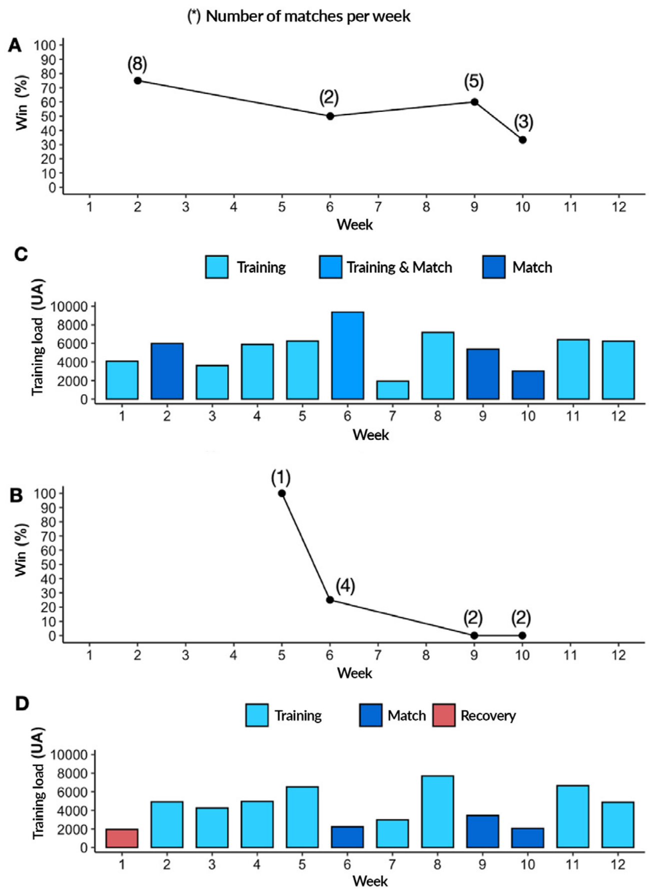

Figure 4. *Victory (%) (A & B) and training load distribution (AU) (C & D) of player #1 (A & C) and player #2 (B & D) over 12 weeks.*

Pôle France train in accordance with the programmed and recommended intensity distribution by adopting a "pyramid" model of intensity distribution. From a metabolic point of view, these young players, aged 14 on average, are in (or close to) their peak of rapid growth (Sempé & Pédron, 1971). Prior to puberty, children rely mainly on the aerobic pathway for energy production. However, during this pubertal growth peak, there is a transition to a greater use of the anaerobic pathways that produce metabolites that cause muscle fatigue (Kenney et al., 2021; Ratel & Blazevich, 2017). Therefore, from the peak of growth velocity, it is essential to offer a high volume of low intensity aerobic training (Zone 1) in order to delay fatigability, facilitate recovery and optimise technical work (Ratel, 2018). This is done using "polarised" and "pyramid" training models depending on the sporting objective of the season.

Concerning the distribution of intensities carried out according to the RPE, the players have a "homogeneous" perception of the time spent in each intensity zone (Zone 1: 35.0 ± 15.4 %; Zone 2: 38.5 ± 8.4 %; Zone 3: 26.4 ± 11.9 %). This means that sessions programmed in Zone 1 are in fact sessions where players feel in Zone 2 or even 3. This significant difference between the distribution of programmed intensities and that of the RPE results (Figure 2A & 2C) may be due to the intermittent nature of tennis. Indeed, this alternation of short high intensity efforts and short recovery breaks on an aerobic endurance background leads to a production and accumulation of muscle metabolites (e.g., ammonia, protons, lactate) which could contribute to increase peripheral sensations of fatigue (Mutch & Banister, 1983) and therefore RPE (St Clair Gibson & Noakes, 2004). This overestimation could also be explained by an increase in central sensations linked to the intermittence of the heart rate during repeated efforts. Thus, the fatigability of tennis training sessions would be underestimated if only heart rate is considered as an indicator of internal load. Another explanatory factor could be the age of the players. Indeed, Groslambert & Mahon (2006) found a poorer correlation between RPE and heart rate during incremental exercise in adolescents than in adults. Furthermore, peripheral factors (i.e., maximal lactate, maximal minute ventilation, and mechanical work output) appeared to explain only 36% of the variance in RPE measured with the CR-10 during intense exercise from childhood to adolescence (Bardin et al., s. d.). This suggests that other psychosocial factors may be important in estimating RPE during exercise. Thus, although RPE, which considers the involvement and intuition of each player, is a useful monitoring tool for the coach to simply assess the perceived effort of the session, it would be necessary to quantify the intensity of training with both physiological and psychometric variables in young categories.

Regarding training load, the average (respectively 5373 AU and 4381 AU for players #1 and #2) imposed over the 12 weeks is similar to that of young players in futsal (15.8 ± 0.8 years) (Moreira et al., 2013) and basketball (19 ± 1 years) (Moraes et al., 2017) where the training load does not exceed 6000 AU. In addition, the training loads of the technical/tactical sessions (512.5 ± 191 AU) are similar to those observed for Australian players aged 17 ± 1.3 years ranked 135 ± 22 in the International Tennis Federation junior and 1309 ± 370 in the Association of Tennis Professionals who had a load of 492 ± 304 AU (Murphy et al., 2015). However, some weeks (e.g., weeks 6 and 8 Figure 4) have training loads above 7000 AU. These high training loads are due to weeks with high volume sessions (more than 2 h training per session). Long training sessions are perceived as difficult because of their long duration, and the associated level of perceived exertion is multiplied by the duration of the effort (Foster et al., 2001). As a result, the duration of the effort is taken into account twice, which tends to overestimate the loads for high volume training situations (Martin, 2018). However, these weeks with high training loads are automatically followed by a week with a load of less than 4000 AU, which shows that the previous weeks are considered to plan the training in the most optimal way. We observe that the organisation of the training loads allowed half of the players to maintain good performance while minimising any risk of injury. In contrast, the other half of the players had a negative win percentage (n = 2) or did not play any official matches (n = 2) due to injuries. This suggests that the training load was not planned in the most judicious way. In order to reduce training-related injuries in the long term, Gabbett (2016). The importance of monitoring the training load is emphasised.

CONCLUSION

The present results show that young elite French tennis players train 70-75% of the time in a low intensity zone, about 20% in a moderate intensity zone and 3-5% in a high intensity zone. These data therefore demonstrate that a "pyramid" training model is used. In addition, the age of the players is a factor confirming the importance of aerobic work during training. However, the players overestimated the intensity of their efforts (moderate to intense intensities) compared to the prescribed training intensity and the actual training intensity (heart rate). This overestimation can be explained by the intermittent nature of tennis and the age of the players in this study. Therefore, it seems essential to couple heart rate with RPE in future studies. Furthermore, the programmed training load was like that observed for players of the same age at a high level. We can conclude that for half of the players, this planning allowed them to maintain good performance while minimising the risk of injury. The results presented here can therefore be seen as a first step towards the recognition of the necessary distribution of the actual training intensity performed by young tennis players. Tennis coaches will now be able to compare the training loads of their players with the results presented here. In addition, tennis coaches can use the current training monitoring methods adopted in the present study to verify the internal training load of their players. The use of such an approach should allow coaches to adjust the training load to avoid the phenomenon of 'overtraining'. As the current data are on young male players, further studies on female tennis players are needed. The use of heart rate variability monitoring can also complement the monitoring of individual physiological response over time (Schmitt et al., 2006).

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"Compete-Learn-Honor®": A psychological and sports science evidence-based approach to coaching and player development

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ABSTRACT

This article describes the research that supports "Compete-Learn-Honor," a psychological and sport science evidence-based coaching philosophy and player development approach to promoting emotional and physical safety, fun, and growth as a person and player. Compete-Learn-Honor (CLH) focuses on the mental-emotional game but enables task- and mastery-oriented rather than ego-oriented integration of all six general tennis performance components for periodization identified by the U.S. Professional Tennis Association: Physical, technical, tactical, strategic, mental, and environmental. The article describes how CLH is implemented, and reviews how CLH is rooted in the science of positive psychology and of creating a task- and mastery-oriented player development climate in sport that focuses on support for basic ABC needs of human motivation—autonomy, belonging, and competence, all of which has been shown to promote better athlete well-being and performance.

Key words: coaching philosophy, mental strength, mental skills, character development, player well-being

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INTRODUCTION

A core challenge for coaches at all levels, and particularly for coaches of juniors in the rapid growth phases of middle childhood and adolescence, is how to guide athletes to increased sport competence and performance success while also strengthening their mental and social-emotional health. A coach whose athlete wins tournaments but who is unhappy, anxious, and burned-out has not succeeded. Sports participation can have either positive or negative effects (Whitley et al., 2021), and the coach-athlete relationship has been identified as a key to producing positive outcomes, especially the degree to which coaches intentionally integrate life skills and character development opportunities which satisfy broad human needs for autonomy, belonging, and competence (Ryan & Deci, 2000) into their coaching (e.g., Camire et al., 2012; Gould & Carson, 2008).

One approach for creating such a need-satisfying player "learning in development" environment in sports (O'Sullivan et al., 2021) is "Compete-Learn-Honor" (CLH—Scales, 2019; 2020; 2023), which prioritizes effort, continuous growth, and behaving with high character on and off the court over win-lose results. It is a psychological and sport science evidence-based coaching philosophy and player development approach to promoting emotional and physical safety, fun, and growth as a person and player.

Originating in tennis, a coach using the CLH approach intentionally incorporates discussion and activities for building 27 tennis-relevant life skills and character habits into all practices and individual lessons and into season or long-term player development plans (Table 1 lists the 27 habits and definitions). Compete-Learn-Honor focuses on the mental-emotional game, but in so doing also enables task- and mastery-oriented rather than ego-oriented integration of all six general tennis performance components for periodization identified by the U.S. Professional Tennis Association: Physical, technical, tactical, strategic, mental, and environmental (USPTA, 2022). In addition to describing CLH, this article presents some specific exercises and activities coaches can easily integrate, homework athletes can do, etc. to build these mental-emotional habits.

METHODS

The core methodology of CLH is cognitive reframing, most especially helping players redefine success away from a traditional binary of winning or losing, to the more developmental definition of improving as a person and a player by Competing (Give 100% effort at all times), Learning (Be an open, curious, humble learner), and Honoring (By how you act, bring credit to self, everyone else including opponents, and the game). CLH further elaborates what this means by positioning Honor as the foundation for Learning, and all Competitive development, as expressed in these expanded definitions below. Coach-player discussions, posters, videos, worksheets, and other activities (some described below) expand players' understanding of what each of the three CLH pillars means. Specifically, at the start of the season, players do a CLH self-assessment in which they rate themselves on how well they meet these descriptions (rated as a strength, ok but inconsistent, and definitely needs work):

- **HONOR:** I am consistently respectful to all (opponents, teammates, coaches, officials, etc.), use positive self-talk and body language, never give up, don't make excuses, and enjoy playing my sport whether I win or lose.
- **LEARN:** I am striving to learn more about my sport, on and off the playing field. I am humble about my own skills. I take notes and study them. I set improvement as a goal more than winning. I look at my games and matches as a chance to learn, whether I win or lose.
- **COMPETE:** I give my full effort in practices, lessons, games, and matches. I prepare by proper conditioning, correct breathing, and having a game plan and routines. I enjoy the battle and solving the puzzle of a sports contest. I keep my focus on right now when I'm playing.

CLH was developed for the Junior Varsity and Varsity high school tennis player and due to cognitive reframing being at the center of it is therefore most relevant to use with middle school students up through high performance juniors and adult recreational players who have the cognitive abilities to reflect, discuss, and actively practice these principles with a team and on their own so they become habits. However, CLH also is fully consistent with and applicable to the USTA's American Development Model and Net Generation's coverage of character for younger children. For example, the Net Generation Coach's Curriculum (USTA, 2017) includes even at the red ball stage coverage of CLH concepts such as respect for others, the importance of giving one's best effort, kindness and cooperation, following rules, and making good choices, and builds on these at orange and green ball levels to include respect for opponents, teamwork, taking responsibility, being resilient, and goal setting. Similar and related CLH concepts can thus be introduced at those developmental stages to supplement the Net Generation character progressions and lay the groundwork for deeper CLH development at older levels of junior play.

Every day in practice, large laminated posters with one of the 27 CLH habits on them are hung on the tennis fence. After warm-up, players sit in a semi-circle, read the habit aloud, and then discuss in their own words what this habit means to them. The coach summarizes the key points and lessons for both on and off court life, and the habit is reinforced throughout practices and matches all season.

Brief, inexpensively made, 1-2-minute iPhone videos of the coach encapsulating the meaning and application of each habit have been created and are recommended for players to view on a YouTube channel and a website dedicated to CLH (www.competelearnhonor.com). More than three dozen worksheets and activities for individuals and the team have been developed that also are used to introduce and build these CLH habits (Scales, 2023).

Building players' feelings of autonomy, belonging, and competence is a critical aim of CLH. Therefore, when freezing play during practice, or in permitted coaching during matches, the coach sometimes does give directive suggestions for improved effectiveness in all facets of play (e.g., technical, tactical, strategic, mental). But primarily a CLH coach tries to emphasize asking questions of the student-athletes or prompting them to reflect ("tell me the story of the match so far," how can you use your tennis strengths in this situation?"), so that athletes have voice, and are empowered to identify problems and choose their own solutions more than the coach imposing them.

All of these methods are meant to help players lessen the degree to which they are focusing on and ego-involved in the outcome of play—winning or losing—and jumping to judgments about their worth as human beings based on whether they win or lose. The CLH methods are meant to help them focus instead on task and mastery by loving and honoring the game, eagerly learning, and approaching play more objectively as a continuing series of problems or puzzles to enjoy trying to solve.

Several of the 27 CLH principles are listed in the following, and sample activities described for how to promote them. These activities are elaborated in Scales (2023) and several illustrative worksheets used in CLH training are included in Figure 1 of this article.

Honor: Love the Game More Than How You Perform

Sample CLH Activities/Worksheets:

*Complete What I Love About Playing Tennis worksheet, adapted from Lauer et al. (2010).

*Use the positive reasons why you play tennis to construct a between-points routine that enables execution of the "4Rs" in the time between points: Key words and body actions that help you to Respond positively, Relax, Refocus on the next point, and be Ready to play.

*Complete the Excuses List (favorite excuses heard of or personally use) to throw away into the "Excuse Box" (literally a cardboard box at the entrance to the tennis court) so you as a person and player take responsibility for what happens.

Learn: Humility Allows You to Learn

Sample CLH Activities/Worksheets:

*Complete Tennis Skills Self-Assessment

*Complete Goals and Obstacles Worksheet

*Complete Learning From Losses Worksheets

*Use Match Notes Worksheet for post-match summary and learning

*Conduct Fake Post-Match Interview (respond in a respectful and mastery-oriented way to the question "Did you win?") to frame all outcomes, whether a win or a loss, as learning opportunities.

Compete: Love the Battle and Solve the Puzzle

Sample CLH Activities/Worksheets:

*Complete 3 Essential Tools worksheet (Game Plan, Serve + 1 and Return + 1 plays, a 4R's between-points routine)

*Complete What Am I Working On Today Worksheet before practices and matches, to stay focused on a learning and improvement focus rather than a win-lose outcome focus.

Table 1

The Compete-Learn-Honor habits.

CLH Habit	Definition
HONOR	
1: Respect All	Respecting ourselves, our teammates, coaches, opponents, officials, family, school, community, and the game we play. Building everyone up and being a great supportive teammate. Treating every player as equally valuable and cared about, regardless of their skill level or ranking, or other differences.
2: Love The Game More Than How You Perform	Loving the game and the process of improving more than how we do at it, recognizing that the game is bigger than we are. Giving every benefit of the doubt to our opponent, playing by both the letter and spirit of the game's rules and codes of conduct regardless of the effect on winning and losing.
3: Do Not Strive For Victory: Strive For Gracefulness, Balance, Patience, Clarity	Focusing on movement, being unrushed, having a plan.
4: Use Positive Self-Talk and Show Positive Body Language	Using positive self-talk and physically projecting an attitude of confidence (not cockiness).
5: Never Give Up	Maintaining belief that there is always a chance to play better and improve, even in a loss, or additionally get lucky and win.
6: No Excuses	Taking responsibility for how we play, and not making excuses or blaming other people or factors.
7: Give Your All	Committing to high energy and full focus, and giving attention to detail.
LEARN	
8: Lose Your "Self": Humility Allows You To Learn	Being open, curious, and humble learners. Coach being enthusiastic about partnering with parents and helping parents learn why coaches do what they do, so parents grow in their interest in and appreciation of the game their child is playing.
9: Mental Toughness Isn't Given—It's Developed	Feeling you can always get better as long as you put in the work.
10: Adjust-Adapt-Survive	Being flexible and adaptable as circumstances change.
11: Learn One New Thing Every Time On The Court	Creating a personal and team continuous improvement culture; treating self and others as lifelong learners, from coaches and parents to experienced players and those brand new to the game.
12: Take Notes And Then Study The Notes	Reflecting on practice and competition experiences.
13: Improving Is A Better Goal Than Winning	Focusing on growth process more than outcome.
14: Mistakes Are Necessary To Improve	Creating a personal mindset and team culture where it's emotionally and physically safe to try new skills and not succeed at first.
15: Play The Ball, Not The Opponent	Ignoring rank and reputation of opponent without failing to notice and manage their strengths and weaknesses.
16: Always Change A Losing Game—Never Change A Winning Game	Being able & willing to adjust behavior on the basis of new data coming from competitive play.
COMPETE	
17: Think During Practice—Feel During The Match	Using progressions, repetitions, and accumulated rehearsal of breaking complex behaviors into smaller segments in order to play instinctively in competition.
18: Physical Fitness Leads To Mental Toughness	Taking care of mental and physical health through exercise, proper nutrition, and adequate rest.
19: Proper Breathing Leads To A Relaxed Body And A Clear Mind	Using proper athletic breathing techniques to improve attitude and performance.
20: Love The Battle And Solve The Puzzle	Enjoying the process of preparation and competition, and pitting skills and wits against an opponent, versus only having fun if win.
21: Have A Game Plan And Routines	Having a systematic approach to play based on analysis of self and opponent's strengths and weaknesses.
22: Have A Purpose And A Target For Every Stroke	Having an overall strategy and specific tactics for different situations.
23: Expect The Ball To Come Back And Expect A Tough Shot	Assuming the opponent is as good as you and will work as hard as you in competition.
24: What Matters Is Right Now, This Point, This Shot	Staying in the present moment, neither over-thinking the last point/play nor projecting outcome thoughts onto points that haven't even been played yet.
25: All Points Are Big Points	Considering every moment of a contest to be a potential turning point
26: Use Time Effectively	Taking time away from opponent and giving to self, within the letter and spirit of the rules.
27: Combat Stress By Being Humble, Smiling, Moving, Drinking Water, And Having A Plan	Having competition-doable strategies for lowering feelings of tension, nerves, and stress.

WHAT DO YOU LOVE ABOUT PLAYING TENNIS/PICKLEBALL?

Worksheet

Worksheet modified from USTA Mental Drills and Skills Handbook, Worksheet 6-1

By Larry Lauer, Daniel Gould, Paul Lubbers, & Mark Kovacs, Eds. (2010). USTA Mental Skills and Drills Handbook. Monterey, CA: Coaches Choice.

Instructions: The purpose of this exercise is to help you develop motivating cue words, phrases, and images. To create these, you first need to remember WHY you play tennis or pickleball. What drives you to compete? So, respond to this question, keeping in mind your personal reasons for playing tennis or pickleball.

Why do you play tennis or pickleball? What do you love about playing tennis or pickleball? (Think about why you started playing tennis or pickleball, the aspects of the game you enjoy, and your long-term goals, such as, I enjoy competing against others.)

____
____
____
____
____
____

Now highlight all the personally meaningful cue words, phrases, or images in your answer.

Re-read this before practices and matches.

And use those words in-between points (your 3 or 4R's routine) to keep yourself positive and focused on what you love about playing, no matter what else is going on!

Figure 1. *Sample CLH Activities and Worksheets (Scales, 2023).*

RESULTS

Emerging qualitative and quantitative data suggest the usefulness of the CLH approach. For example, an initial study with 262 middle and high school student-athletes from across the U.S. and representing more than one dozen team and individual sports, including tennis, found strong support for the impact of CLH: Logistic regression analysis showed that student-athletes who described their team climate as high in the principles of Compete-Learn-Honor reported significantly greater odds of having social-emotional competence (14 times more), strong relationships with their coach (30 times more), confidence in their coach (46 times more), deriving a sense of purpose and meaning from their sport (2 ½ times more), and strongly intending to continue playing their sport (3 times more; Scales et al., 2023) than student-athletes who didn't have high levels of a CLH team climate. The latter outcome, intent to continue playing, is especially promising given that national data show as much as 70% of young people quit their sport by the age of 13, largely because they are no longer having fun, due to having poor relationships with their coach and/or too much emphasis on winning (Aspen Institute, 2019).

Qualitatively, the experience of CLH principles being used with the #1 player on a college women's tennis team is illustrative of its effectiveness. The player was performing below her expectations and being deeply critical of even her effective play, to the point where she was frequently upset, hitting her leg in anger with her racquet, and having little fun playing. One CLH activity, Judo-ing Negative Words to Positive, was used to intervene in this cycle. The player used her phone to keep track of several days' worth of words and body language she used after points in her practice matches. The consultant then helped her identify patterns of words and body language that were "ineffective" and "unproductive," using those words to describe her play instead of "bad," or "good." Then together the student-athlete and consultant constructed words and body actions that would be more effective. Just starting to say the word "okay" after each point as a sign of acceptance that the point was over and to move on was a simple step that helped the player react more neutrally to points, whether won or lost, and better observe how they had been won or lost. The player also agreed to set a goal of at least 50% of the time, not hitting herself with her racquet but missing her leg on purpose, to remind her that she had control and autonomy over this behavior. Within several weeks her demeanor had become so calm in words and actions and her enjoyment so much increased that she shared that her teammates thought she was winning all the time, when in fact she was winning matches more than before but like most players, still losing a lot of points and games, but now taking it less personally and observing it more objectively. Similar examples have been seen frequently at the high school level, some of which are related in Scales (2019).

DISCUSSION/LITERATURE

Motivation and Self-Determination Theory

It is well established in the psychological and sport science research that athletes who prioritize winning over development and improvement generally enjoy their sport less, are more depressed and anxious, more worried about making mistakes, less satisfied, and perform worse than athletes who are task- and mastery-oriented, who want to win and compete to win but who are not consumed by the outcome (Bean et al., 2014; Cronin, 2015; Houltberg et al., 2018). Likewise, coaches who create a task- and mastery-oriented player development climate that focuses on support for basic ABC needs of human motivation—autonomy, belonging, and competence—have athletes who work harder, are more persistent in the face of challenge and disappointment, more open to learning through mistakes, psychologically and social-emotionally healthier, enjoy playing more, and perform better than athletes who have coaches that focus on winning as the outcome and who use controlling coaching strategies that thwart those needs for autonomy, belonging, and competence (Mallet & Cote, 2006, Rocci et al. 2020; Small et al., 2011; Whitley et al., 2021).

The CLH approach is well-aligned with such studies and with psychological and sport science theories of learning, motivation, and development. For example, it directly reflects Gould and Carson's (2008) model for coaching life skills through sports. In that model, a well-articulated coaching philosophy, the coach's relationship skills, competence, and accessibility interact with athletes' existing personal and external assets to enable both direct (e.g., opportunities for leadership, setting clear and consistent rules) and indirect strategies (e.g., being a role model for desired values and behaviors) that affect athletes' identity formation, perceived competence, locus of control, self-worth, and autonomy (Camire, Trudel, & Forneris, 2012).

The CLH approach also well reflects Cote's Development Framework for Sport, Duda's taxonomy (Bean, Fortier, Post, & Chima, 2014) that integrates both Self-Determination Theory (SDT) and Achievement Goal Theory (AGT), USTA's American Development Model (ADM; Davies, Allen, & Roetert, 2021), and Houltberg and Sholefield's (2020) Developmental Model of Elite Athletes. CLH embodies these theories and frameworks in the following ways:

1. It is intended to create an empowering, respectful, mastery-oriented context (per AGT) that is
2. Fun, positive, engaging, and inclusive rather than focusing on wins and losses (per ADM)
3. And in which the teaching of life skills to student-athletes is intentional (Gould & Carson, 2008) and meant to
4. Promote the "ABC's" articulated in SDT (Ryan & Deci, 2000) of Autonomy (choice, control, engaging in intrinsic interests), Belonging (positive relatedness to others), and Competence (being skilled at things that have value to self and valued others), while
5. Helping athletes connect personal and social values to playing, which enables development of a narrative of larger purpose than just performance (Houltberg & Sholefield, 2020).

The research on sports and the ABCs of self-determination theory shows that:

"...when coaches, parents, or fellow players become controlling or critical (which is often potentiated by their own ego-involvement in winning) they can undermine feelings of competence and autonomy that are the foundations of sustained motivation. Players will report that the game is no longer fun as a reason for dropout, but this will in turn be explained by the absence of feelings of autonomy and competence" (Ryan et al., 2009, p.111).

The more autonomy support within a positive coach-athlete relationship an athlete feels, the evidence shows that the more they are likely to hang in there and persevere when facing those challenges and obstacles, to actually perform better, and to enjoy it all more (e.g., Camire et al., 2012; Cronin, 2015). And when coaches support autonomy through encouragement, positive feedback, and helping their athletes pursue intrinsic goals that come from their heart—what we have called "sparks" (Benson & Scales, 2009)—more than external rewards, then athletes have more emotional and physical energy, and compete better (Ryan et al., 2009). That relationship-centered autonomy support is a central feature that Compete-Learn-Honor is intended to promote—working together in healthy relationships with a community of others, from coaches, students, and parents to teammates and opponents, to find and grow that deeply personal spark and larger purpose for playing the sport, in our case, tennis.

Studies of high-achievers both in and outside of sports show (e.g., Houltberg et al., 2018; Loehr, 2012; Ryan et al., 2009) that extrinsic goals (such as winning, or recognition), even if reached, rarely leave the athlete feeling satisfied unless they also have these more deeply personal, intrinsic goals underlying their effort and participation (such as attaining personal bests, improving, loving the battle, contributing to team effort).

Life Skills and Character Development

Sports are often seen as a vehicle for developing key life skills and character strengths, but as Theokas et al. (2008) well described, "there is nothing about sport itself that is magical... (p. 72) and "there is nothing about a ball...that teaches life skills" (p. 78). In addition to being rooted in the above psychological and sport science research and theory on motivation and self-determination, the 27 CLH habits also are potential pathways for helping coaches be intentional about promoting developmentally impactful relationships with their athletes, and athletes' life skills and character development through sports.

For example, pioneering performance psychologist Dr. Jim Loehr (2012) divides character strengths into two broad classes: Performance (strengths that govern our relationship with ourselves) and Moral (strengths that govern our relationships with others). He describes how performance strengths help us succeed by society's scorecard, but that moral strengths help us succeed as human beings. Performance character strengths include effort investment, perseverance, determination, confidence, focus, and competitiveness. Moral character strengths include respect and care for others, humility, fairness, generosity, and honor. Peterson and Seligman (2004) also identified similar character strengths that their research showed to be broadly universal across societies and cultures, including love of learning, persistence, love, teamwork, modesty, gratitude, and hope. Finally, the United States Tennis Association Player Development program (USTA, 2022) defines 7 Values and 12 Skills of a True Champion, including the values of being engaged, confident, resilient, professional, respectful, determined, and tough, and the skills of self-awareness, focus, goal setting & striving, disciplined self-talk, visualization/imagery, confidence, resilience, stress & energy management, relaxation & breathing, communication, leadership, and time management, prioritization, and organization.

Each of the 27 CLH habits is grounded in and meant to strengthen one or more of these performance and moral life skills and character strengths. Applying Loehr's (2012) language, the CLH habits are meant to enhance performance character while being rooted in developing moral character. For example, the very first CLH habit, under the pillar of Honor, is Respect All. If coaches and players are truly Respecting All, then that implies that the coach and players are treating every player as equally valuable and cared about, regardless of their skill level or ranking, or other differences in background. If everyone is being treated as equally valuable, then this should enhance a learning and player development climate of caring, trust, belonging, teamwork, and humility, among other life skills and character strengths.

Research has shown that when coaches create a climate focused on task mastery, support for meeting athletes' autonomy, belonging, and competence needs, and explicit attention to these kinds of life skills and character strengths, players have better mental and social-emotional health and are more likely to perform at personal best levels. For example, Gould et al. (2012) found that when coaches built positive rapport with their athletes and were intentional about teaching how sport lessons are related to broader life, their athletes had better emotional regulation, cognitive skills for managing competition, and prosocial norms in relating to others, including opponents. Gearity (2012) also concluded in reviewing the research that winning coaches focus on developing the psychological skills and well-being of their athletes, and that poor coaches fail to intentionally teach and facilitate mental, life, and character skills. Gould and Carson (2010) also found that highly effective high school coaches in terms of winning records were highly motivated to win, but also made the "personal development of their players a top priority" (p. 301). Crucially, they had a well thought out coaching philosophy, clear expectations, were skilled at building relationships, and integrated teaching of life skills into "everything they did as coaches" (p. 302).

The 27 habits within the three pillars of Compete-Learn-Honor provide a way for coaches to systematically and simply integrate a task and mastery approach to player development, in ways that meet players' basic motivational needs for autonomy, belonging, and competence, and that explicitly connect and integrate development as a person and a player through their core emphasis on growing life skills and character strengths both on and off the court.

CONCLUSION

The initial quantitative study examining the association of a CLH team climate with positive sport outcomes among middle and high school student-athletes (Scales et al., 2023) showed that CLH, as expected, was associated with better social-emotional strengths, relationships with and confidence in the coach, meaning and purpose derived from their sport, and intention to keep playing their sport. Future research is needed to build on this study and examine this plausible theory of change for CLH suggested by the broader literature and initial study: That if coaches systematically use CLH and players systematically apply it, then players will be more likely to feel safe, have fun, feel healthy mentally, socially, emotionally, and physically, improve their consistency and performance level in tennis, and want to stay active in tennis more so than players who are not exposed to a systematic CLH approach.

Even as that needed research is undertaken, however, coaches, other sport psychology practitioners, and researchers deciding to use the CLH approach can feel confident that both the initial quantitative results and theory and research in human motivation, character development, and sport participation provide substantial scientific validity for the mental-emotional principles and habits that define those three pillars of Compete, Learn, and Honor.

CONFLICT OF INTEREST AND FUNDING

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A test battery to assess on court displacements of youth tennis players

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ABSTRACT

This paper propose five tennis-specific tests performed on hardcourt to analyze coordination of lower limbs and laterality. Times to complete one 20 meters linear sprint and four 4 x 5 meters shuttle sprints (180° change of direction) in: a) open stance, b) neutral stance, c) forehand and d) backhand, were recorded in 342 youth tennis players aged 11-16 yrs. Differences between times in the 20 meters and 4 x 5 meters sprints in open stance greater than 3.13 and 2.91 seconds denote inadequate on-court displacement capacity of females and males respectively. The difference between open and neutral shuttle sprints assess the on-court coordination capacities of lower limbs with expected optimal result below 0.43 and 0.39 seconds for females and males respectively. The difference between forehand and backhand shuttle sprints should tend towards zero seconds in symmetric players indicating the capacity to move in the court with the same acceleration/deceleration capabilities regardless laterality. These tests can be proposed at any age as they give an idea of the coordination capacities of lower limbs and laterality related to specific tennis movements. The earlier age assessment may serve to address any coordination/laterality deficits sooner versus later.

Key words: change of direction, laterality, symmetry

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INTRODUCTION

Tennis players need to master the complex techniques and movement patterns on the court, requiring acceleration and deceleration in combination with changes of direction (Kovacs, 2006; Hoppe et al., 2014). It has been reported that approximately 70% of tennis movement is lateral (Weber et al., 2007). However, athletes may have identified differences in movement to either side which should be trained accordingly (Eng & Sundar, 2021).

In modern tennis, training must be personalized beginning at youth ages which are 5-7 yrs (Fitzpatrick et al., 2017). Thus, functional assessment should be initiated early and consider not only the physiological characteristics, but also tests that can give information to the trainers regarding speeds and changes of directions (COD) specific for tennis. Such tests include but are not limited to strength-speed training, technical training, and anticipation training (Eng & Sundar, 2021).

Strength-speed characteristics have been investigated by various authors, also focusing on lateral acceleration, as summarized in the recent paper of Eng & Sundar (2020). High ranked players typically run 0.25 to 0.50 meters more to the forehand side than the backhand side (Weber et al., 2007). Largest leg strength differences were found in lateral movement by single leg countermovement lateral jumps, and it was suggested that up to 15% difference was normal and acceptable (Hewit et al., 2012). That is, an athlete might be 15% weaker in one leg than the other without detrimental loss of speed (Eng & Sundar, 2021).

Eng & Sundar (2021) observed that 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. The authors suggest that 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 (Eng & Sundar, 2021).

Aim

Considering the complexity of the topic, in this paper we want to contribute to the discussion about lateral movements, focusing on the analysis of the symmetry/asymmetry of lower limbs performances of youth players assessed by a new proposed battery of tennis specific tests.

METHODS

A test battery was developed considering that around 3-4 rallies are usually played to score. This implicates 3 to 4 COD, with an average distance lower than 5 meters each (Parson & Jones, 1998; Ferrauti et al., 2003). From this observation, a distance of 5 meters performed 4 times equates to 20 meters was chosen to measure the maximum linear speed (Test 1).

The 20 meters distance was then considered as reference and subdivided into four 5 meters subsequent sprints with three 180° COD, as indicative of both acceleration and COD capacities.

These shuttle sprints with COD were proposed both in open (Test 2) and in neutral stance (Test 3). Sprints with COD in open stance are aimed to measure the displacement capacity arriving with both feet parallel in front to the net at the moment of impact with the ball (Figure 1). This situation is utilised by top level players in most of the cases during the matches (Reid et al., 2013).

Figure 1. *Sprint with COD in open stance arriving with both feet parallel in front to the net.*

Sprints with COD in neutral stance are aimed to measure the displacement capacity arriving with both feet perpendicular to the net at the moment of impact of the ball (Figure 2), and it is utilized in the remaining few cases.

In both sprints with COD the lower limbs can assume the attitude to perform the forehand or the backhand shot. Thus, sprints with COD with forehand and backhand shot measures the displacement capacity only utilizing the forehand or the backhand shot respectively, without utilizing the racket, but only mimicking the technical movement.

Figure 2. *Sprints with COD in neutral stance arriving with both feet perpendicular to the net.*

In summary, the proposed test battery consist of five tests, all performed on synthetic courts:

- Test 1: 20m linear sprint.
- Test 2: shuttle 4 x 5m sprints with COD open stance.
- Test 3: shuttle 4 x 5m sprints with COD neutral stance.
- Test 4: shuttle 4 x 5m sprints with COD forehand.
- Test 5: shuttle 4 x 5m sprints with COD backhand.

In tests 2, 3, 4 and 5 players at COD must touch with the hand the summit of a cone of 50 cm height.

Each test was performed twice, with a minimum rest of one minute in between. Times between the starting movement and the crossing of the finish line in the 20 m sprint test, or the starting/finish line in the sprints with COD tests, were recorded with an electronic chronometer (Racetime2, Microgate, Italy).

Tests were performed indoor in hardcourts (Play Flex Cushion, Italy; ITF certified Class 3) after 15 minutes of warmup consisting in a sequence of running around the court, accelerations/decelerations and changes of directions, of increased speed. In the training session preceding the testing session, players performed some trials aimed to familiarize with the correct execution of tests.

Three hundred and forthy-one youth tennis players of different gender and age participated in the study after obtaining their affirmative agreement to participate from the Institutional Review Board and the signed informed consent from their parents/guardians, according with the Helsinky declaration of human rights. They were recruited during the training camps organized by the Italian Tennis Federation for selected youth players. Test were performed under the supervision of the same certified trainers.

The anthropometrical characteristics of the subjects are reported in Table 1.

Table 1

Anthropometrical characteristics of the subjects (mean±SD). BMI: Body Mass Index.

Age Category	Females				Males			
	n	Weight (kg)	Height (m)	BMI (kg/m^2)	n	Weight (kg)	Height (m)	BMI (kg/m^2)
U11	48	37.1±7.2	1.48±0.07	16.7±1.8	45	38.8±5.3	1.50±0.08	17.3±1.6
U12	65	43.3±5.1	1.53±0.08	18.5±1.8	72	44.1±5.1	1.57±0.07	17.9±1.8
U13	20	48.1±6.0	1.62±0.09	18.3±1.4	13	50.9±7.1	1.66±0.07	18.6±2.2
U14	9	58.2±9.6	1.72±0.11	19.6±1.6	14	52.9±7.1	1.65±0.06	19.2±1.7
U15	15	65.5±6.9	1.78±0.08	20.7±0.8	13	56.2±6.2	1.70±0.07	19.5±1.7
U16	10	69.7±9.0	1.76±0.06	22.5±2.2	17	61.1±5.4	1.68±0.07	21.6±1.7

Data were analyzed by descriptive statistics. Differences between genders and tests performances were assessed by unpaired T-test assuming $P<0.05$ as significant.

RESULTS

Results are shown in table 2 and 3 for females and males respectively.

Table 2

Results for female tennis players (mean±SD).

Age	n	20 m sprint (s)	4 x 5 m open stance (s)	4 x 5 m neutral stance (s)	4 x 5 m forehand (s)	4 x 5 m backhand (s)	Difference between 4 x 5 m open and 20 m (s)	Difference between 4 x 5 m neutral and open (s)	Difference between 4 x 5 m forehand and backhand (s)
U11	48	3.95±0.24	6.92±0.36	7.44±0.49	7.09±0.45	7.01±0.37	2.97±0.26	0.53±0.35	0.09±0.39
U12	65	3.82±0.23	6.65±0.44	7.27±0.46	6.94±0.44	6.93±0.43	2.83±0.36	0.62±0.30	0.01±0.30
U13	20	3.35±0.09	6.23±0.20	7.12±0.16	6.35±0.24	6.34±0.25	2.89±0.21	0.88±0.19	0.01±0.14
U14	9	3.34±0.13	6.27±0.21	7.15±0.07	6.25±0.28	6.30±0.17	2.92±0.16	0.88±0.18	-0.05±0.18
U15	15	3.33±0.13	6.14±0.19	6.90±0.21	6.18±0.24	5.87±0.23	2.81±0.17	0.76±0.14	0.31±0.19
U16	10	3.40±0.20	6.29±0.33	6.97±0.27	6.08±0.42	6.12±0.47	2.89±0.32	0.68±0.31	-0.03±0.22

Table 3

Results for male tennis players (mean±SD).

Age	n	20 m sprint (s)	4 x 5 m open stance (s)	4 x 5 m neutral stance (s)	4 x 5 m forehand (s)	4 x 5 m backhand (s)	Difference between 4 x 5 m open and 20 m (s)	Difference between 4 x 5 m neutral and open (s)	Difference between 4 x 5 m forehand and backhand (s)
U11	45	3.95±0.24	6.81±0.43	7.19±0.38	6.88±0.39	6.89±0.45	2.86±0.32	0.38±0.35	-0.01±0.27
U12	72	3.85±0.19	6.54±0.33	7.00±0.38	6.67±0.36	6.64±0.38	2.69±0.26	0.46±0.30	0.03±0.29
U13	13	3.52±0.18	6.10±0.17	6.90±0.26	6.22±0.34	6.06±0.19	2.59±0.22	0.79±0.22	0.16±0.37
U14	14	3.41±0.19	5.87±0.29	6.89±0.34	6.09±0.25	6.04±0.26	2.46±0.35	1.02±0.44	0.05±0.21
U15	13	2.99±0.07	5.64±0.16	6.38±0.13	5.78±0.20	5.60±0.25	2.65±0.15	0.77±0.20	0.19±0.25
U16	17	2.90±0.07	5.55±0.07	6.28±0.49	5.58±0.16	5.55±0.17	2.65±0.25	0.73±0.30	0.03±0.15

Table 4

Differences between female and male youth tennis players.

Age	n	20 m sprint (s)	4 x 5 m open stance (s)	4 x 5 m neutral stance (s)	4 x 5 m forehand (s)	4 x 5 m backhand (s)	Difference between 4 x 5 m open and 20 m (s)	Difference between 4 x 5 m neutral and open (s)	Difference between 4 x 5 m forehand and backhand (s)
U11	NS	NS	P<0.05	P<0.01	NS	NS	P<0.025	NS	-0.01±0.27
U12	NS	NS	P<0.001	P<0.001	P<0.001	P<0.01	P<0.005	NS	0.03±0.29
U13	P<0.0025	P<0.05	P<0.01	NS	P<0.001	P<0.001	NS	NS	0.16±0.37
U14	NS	P<0.001	P<0.01	NS	P<0.005	P<0.001	NS	NS	0.05±0.21
U15	P<0.001	P<0.001	P<0.001	P<0.001	P<0.0025	P<0.01	NS	NS	0.19±0.25
U16	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.05	NS	NS	0.03±0.15

DISCUSSION

As expected, performances of youth female and male tennis players in the proposed test battery tend to improve with age according with growth and development, showing not always better results in males compared to females (table 4).

The difference between times in the 20 meters test and the 4 x 5 meters sprints with COD in open stance assess the decrease of speed passing from the linear running to COD in the tennis court. Considering these mean difference times as shown in tables 2 and 3, and adding one Standard Deviation from the mean, it can be assumed that differences greater than 3.13 and 2.91 seconds denote inadequate displacement capacity on the court of female and male youth tennis players respectively.

The difference between open and neutral sprints with COD assess the coordination capacities of lower limbs in the tennis court. The expected optimal result is below 0.43 and 0.39 seconds for female and male respectively, while differences higher than 1.00 seconds appear to highlight a lack of in-court neuromuscular control of the lower limbs.

The difference between forehand or the backhand sprints with COD assess the displacement capacities utilizing these two techniques. In the symmetric players it should tend towards 0.00 seconds indicating the capacity to move in all areas of the court with the same acceleration/deceleration capabilities regardless laterality.

This is a descriptive study not-exempt from limitations, such as the non-homogeneity of the groups in terms of number of players, biological maturity, physical and technical capacities. Furthermore, the cut-off times proposed to consider as sufficient or insufficient the performances in the tests should be more deeply analyzed in the future. Other limitation is that players performed the tests without hitting the ball with the racket.

Finally, another limitation is the only hardcourt utilized for the tests. It is well known that different surfaces affect the performances of the players (Martin & Proiux, 2015) thus, the same surface must be utilized for comparisons.

CONCLUSIONS

Unlike the general fitness tests, those proposed in this paper highlight the capabilities expressed on the court by youth tennis players with regard to footwork and some aspects of laterality. Analyzing the results of the tests the coach and trainer must focus on some coordination aspects necessary for tennis performances. These tests can be proposed at any age as they give an idea of the coordination capacities of lower limbs in relation to specific tennis movements. We propose, however, that earlier age assessment may serve to address any laterality deficits sooner versus later.

Further studies are needed to better analyze the effects of specific training based on the results of the proposed tests on the tennis performance and how to optimally develop tennis specific coordination of the lower limbs during growth. Other studies should be performed studying high level players and analyzing the different performances in the test carried out on different court surfaces.

CONFLICT OF INTEREST AND FUNDING

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

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RECOMMENDED ITF TENNIS ACADEMY CONTENT (CLICK BELOW)

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Forehand footwork variability in the attacking situation at elite level

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ABSTRACT

The aim of the present study was to analyze the different patterns of forehand footwork in attacking situation at elite level. 498 forehand shots played during rallies and involving forward momentum of the body during the final draw of the US Open tournament held in 2019 and 2021 were analyzed. The results highlighted 6 main footwork patterns involving distinct roles for the front leg and the back leg. In conclusion, technical analysis should consider the dynamic aspect of strokes and coaches should work on the variability of footwork in player development.

Key words: footwork, forehand, technical analysis, variability.

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INTRODUCTION

Generating high ball speed has become a determining factor for success at the elite level. After the serve, the forehand has taken a predominant role in the construction of the point. The preferential use of the forehand may be partly explained by the fact that forehand strokes produce a higher ball speed than backhand strokes for elite players (Landlinger et al., 2012).

In traditional teaching, stance is mainly defined as the static position of the feet at the end of the preparation in relation to the trajectory of the shot. Thus, 4 main variations have typically been described: open stance, semi-open stance, neutral stance and closed stance.

The evolution towards a faster game led players to hit their forehands in a variety of situations related to spatio-temporal constraints that need to define the footwork more dynamically by considering the movement of both feet and legs before, during and after contact. Indeed, a recent study has shown differences in lower limb kinematics when the player moves and hits a forehand with different input speeds (Giles & Reid, 2021). This technical variability has created a growing appreciation for a more functional approach of stroke production using the kinetic chain principle, where forces generated by the lower extremities are transferred through the trunk to the dominant arm and racket (Genevois et al., 2015).

The aim of this study was to highlight the different footwork patterns used at elite level to play a forward attacking forehand stroke in various situations.

METHODS AND PROCEDURES

Sample and variables

The sample included 498 forehand strokes from 21 ATP players (ranking 2-214) during the US Open final draw in 2019 and 2021. All the forehands were played in an attacking situation with a forward momentum of the body. For each forehand we recorded the following variables:

1. The type of footwork pattern: transfer from open or semi-open stance (TFOS), front leg forward hop (FLH), pivot (P), back leg diagonal hop (BLDH), front leg diagonal hop (FLDH), on the run (OTR); the front leg corresponds to the left leg and the back leg to the right leg for a right-handed player.
2. The side of the court on which the contact point occurred: deuce side (DS), ad side (AS)
3. The direction of the incoming and outgoing ball: cross-court to cross-court (cc), down-the-line to down-the-line (ll), cross-court to down-the-line (cl), down-the-line to cross-court (lc)
4. The effectiveness of the shot: winner, generate error, continue, error.

Procedure

Data were collected by systematically observing the movement (type and direction) of both legs during the 3 phases of the shot (preparation, acceleration, and follow-through). The analysis was carried out by two observers, certified tennis coaches, specifically trained for this task. Inter-observer reliability was assessed with the Multirater Kappa Free (Randolph, 2005), reaching a very high degree of agreement (Kappa > 0.80).

Statistical analysis

The distribution of the different footwork patterns was expressed as a percentage of the total number of shots analyzed.

RESULTS

The analysis revealed 6 main footwork patterns.

Their distribution and effectiveness are shown in figure 1.

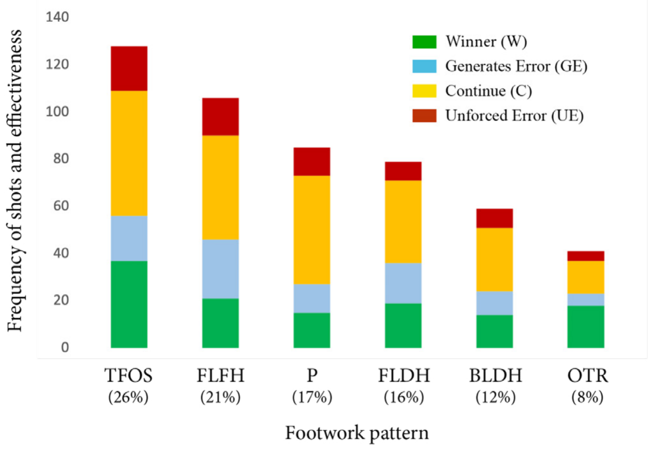

Figure 1. *Distribution of the 6 footwork patterns and their effectiveness.*

Abbreviations: TFOS, Transfer From semi or Open Stance; FLFH, Front Leg Forward Hop; P, Pivot; FLDH, Front Leg Diagonal Hop; BLDH, Back Leg Diagonal Hop; OTR, On The Run.

Figure 2 represents the contact point assuming that the players are right-handed (therefore, for the left-handed player analyzed in this study, the zone has been reversed) and the direction of the incoming and outgoing ball in the different footwork patterns.

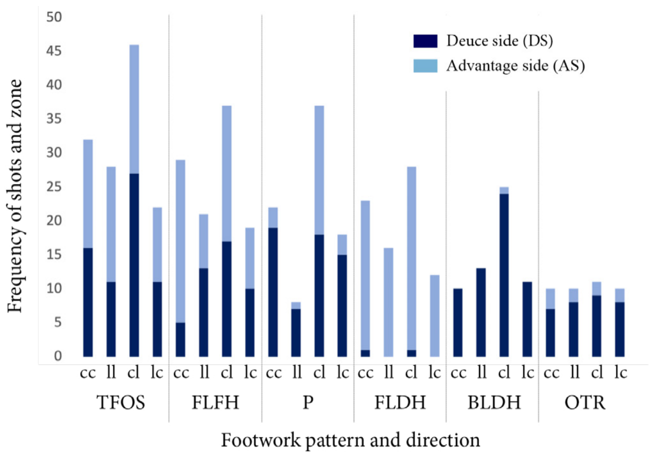

Figure 2. *Distribution of the 6 footwork patterns with its associated direction of the incoming and outgoing ball, and zone of contact.*

It has been observed that players, assuming they are all right-handed, play 52% of their forehands from the deuce side and 48%, from the advantage side. As for the direction of the outgoing ball, 60% of the strokes are down-the-line and 40% are cross-court. Players change direction in 55% of the cases, while they play to the same side than the incoming ball in 45% of the cases. On the deuce side two main footwork patterns are used, BLDH and OTR. On the other hand, FLDH is mainly used on the advantage side. The rest of the footwork patterns are executed on the deuce side or on the advantage side.

Definition of the footwork patterns

1. Front leg on the ground at contact

Figure 3 represents the 3 footwork patterns in which the front leg is on the ground when impact occurs between the racket and the ball.

I. Front leg forward hop (FLFH)

The player usually adopts a square position. The body weight is mainly on the front leg at the moment of contact. After contact, the player lifts off the ground forward and lands on the front leg.

II. Pivot (P)

The player usually adopts a square or semi-open position. The body weight is mainly on the front leg at contact. After contact, the back leg is brought to the side while the front leg pivots to initiate the recovery.

III. Front leg diagonal hop (FLDH)

This pattern is mainly used to run around the backhand to hit a forehand. The body weight is mainly on the front leg at contact. After contact the player lifts off the ground diagonally and lands on the front leg.

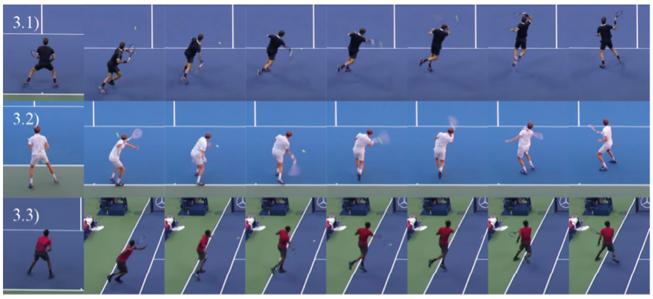

Figure 3. *3.1) FLFH, 3.2) P, 4.3) FLDH. Click on the image to see videos of footwork patterns.*

2. Front leg on air at contact

Figure 4 represents the 3 footwork patterns in which the front leg is in the air at impact between the racket and the ball.

IV. Transfer from semi or open stance (TFOS)

The player starts in an open or semi-open position, with the body weight mainly on the back leg. At contact, the player is in the air with a forward body transfer. After contact, the player lands on the front leg and the back leg is brought to the side to initiate the recovery. The player then moves the back leg to balance and begin repositioning.

V. Back leg diagonal hop (BLDH)

The player starts in an open or semi-open stance with the body weight mainly on the back leg. At contact, the body weight is transferred diagonally with the front leg in the air and carried in front of the body to maintain balance. After contact, the player lands on the back leg first and the front leg makes contact with the ground to initiate recovery.

VI. On the run (OTR)

The player hits the ball while running. Impact with the ball takes place between the ground contact of the back and the front leg, in a stride, without stopping.

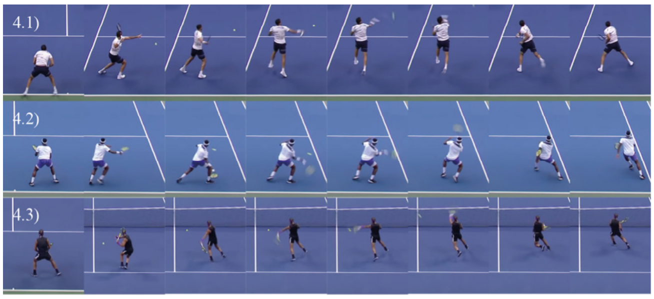

Figure 4. *4.1) TFOS, 4.2) BLDH, 4.3) OTR.. Click on the image to see videos of footwork patterns.*

DISCUSSION

This study highlights the variability of the movement actions for hitting an attacking forehand at elite level. To the best of our knowledge, this is the first time this work has been carried out and, therefore, it does not allow us to compare our results with those of the scientific literature.

In the 6 main patterns analysed, the back leg and the front leg have differentiated roles. The back leg is propulsive and the front leg is stabilising. The differences between the 6 patterns lie in the contact or non-contact with the ground of the front leg at impact and in propulsive orientation of the back leg. Horizontal ground reaction forces have been shown to have the greatest influence on ball velocity (Shimokawa et al., 2020). From a practical point of view, a more intense leg drive could increase the generation of racket head speed through increased angular velocity of the pelvis and trunk (Landlinger et al., 2010; Seeley et al., 2011).

Players play a similar amount of attacking forehands on the deuce side and on the advantage side. This may be because they can be more aggressive with this stroke than with the backhand on the advantage side. Also, they play a similar distribution of shots to the same side than changing direction, perhaps because on some occasions they want to play into empty space while on others they decide to play wrong-foot looking to take advantage in both cases.

PRACTICAL APPLICATION

A better understanding of the dynamics of footwork during the strokes allows coaches to give more adapted technical indications, but also to propose oriented physical exercises that should improve the efficiency of the kinetic chain (Genevois et al., 2016). Among these exercises, medicine ball throws occupy an important place and should be accompanied by ball strikes using the same footwork patterns to accentuate the transfer.

CONCLUSIONS

All types of footwork techniques can be defined as "transfer movements" with variations depending on the direction and intensity of propulsion and the way the body is stabilised. It is recommended that players, from an early age, learn to move effectively around the court to hit any type of ball correctly. The tennis coach and physical trainer should work together to ensure that players move correctly.

CONFLICT OF INTEREST AND FUNDING

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

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The “performance narrative” in junior tennis

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ABSTRACT

Narrative theory states that through creating personal stories people can make sense of their lives and create an identity. The “performance narrative” is a story of single-minded dedication to sport performance, where, winning, results, achievements are pre-eminent and link closely to the athlete’s mental well-being. The “performance narrative” has received attention in professional sports settings, but research has yet to investigate the possible effects on junior tennis players. The purpose of this study was to examine the experiences of 4 UK, elite junior tennis players and describe what it is like to perform in the elite junior context. An Interpretative Phenomenological Analysis of 4 elite junior tennis players describes their insights into elite junior tennis. This study found that (a) participants prioritise results at an early age (b) the “performance narrative” influenced participants attitudes to learning (c) the “performance narrative” reduced participants enjoyment of competition. The findings of this research contribute to an evolving, problematic epistemology of sports coaching and confirms that the performance narrative permeates junior tennis culture, interferes with attitude to learning, and reduces enjoyment of competition. The findings present governing bodies opportunities to inform player, parent, and coach education so the performance narrative does not negatively influence junior tennis players.

Key words: interpretative phenomenological analysis, performance narrative, positive youth development.

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THE “PERFORMANCE NARRATIVE” IN JUNIOR TENNIS.

Every young tennis player has the right to high quality, developmentally rich experiences from tennis. Therefore, it is incumbent on governing bodies, researchers, coaching practitioners, and parents to understand how implicit and explicit behaviours influence the young tennis players experience of our sport.

There are currently no studies which examine the potential impact of sustained participation, from an early age, in a competition system known to prioritise ranking / selection / representation (Lauer et al., 2010); rely on financial investment from parents (Dunn et al., 2016); contain high levels of interpersonal conflict (Wolfenden & Holt, 2005; Smoll, Cumming, & Smith, 2011, Gowling, 2019); display contradictory values associated with winning and learning (Gowling, 2019). Without careful monitoring and criticality of the conscious or sub-conscious messages that children see and hear, it is possible that flawed learning outcomes are absorbed.

Early talent development models prescribed the training of young people as a linear process. The beginnings of sport participation driven by love for the sport. As athletes develop their skills, linear models, prescribe disciplined practice to hone the sport specific skills and then applied in competition. This paper provides evidence that once players reach a high standard of play in competitive events, the “performance narrative” influences players attitudes at an early age, their attitude to learning, and enjoyment of competition.

The “performance narrative” is a story of single-minded dedication to sport performance, where, winning, results, achievements are pre-eminent and link closely to the athlete’s mental well-being (Douglas & Carless, 2012). Linear talent development models that contain the “performance narrative” yield tennis stakeholders who are reliant upon results to gauge the effectiveness of their efforts; sustain motivation to participate; and maintain enjoyment of competition. This paper highlights the “performance narrative” influencing the attitudes of tennis players aged between 11 and 13.

Greater awareness of the “performance narrative” amongst player, parents, and coaches would improve the support on offer to players struggling with motivation, confidence, or enjoyment. Furthermore, a deeper understanding of existing narratives in junior tennis enables governing bodies, coach educators, coaches, and parents to prioritise "narratives" appropriate for long-term, positive emotional development of junior tennis players no matter what their aspirations in tennis are, for example, the "developmental narrative". The developmental narrative tells the story of commitment to improvement and long-term personal development – often rewarding improvement over results (Douglas & Carless, 2012).

This article looks at the experiences of 4 UK elite junior tennis players and illustrates the "performance narrative" beginning to influence their attitude towards tennis. The responses show (a) participants prioritising results at an early age (b) the "performance narrative" influencing attitudes to learning (c) the "performance narrative" reducing enjoyment of competition.

METHOD

This study was an interpretative phenomenological analysis (IPA) of 4 elite junior tennis players in the UK. The participants included 2 males and 2 females aged between 11 and 13 years old. The participants trained in the following areas: Northern England (2) and Southern England (2). Participants were Junior elite, and this was defined as competing at national level competition and above (Rees et al., 2016). Interviews were semi-structured, and the aim was to understand what it was like for participants to play elite junior tennis. Interviews lasted between 45 minutes and 90 minutes and were audio recorded. Interview transcripts were transcribed verbatim, printed out, and analysed following the IPA procedure.

RESULTS

The results show (a) participants prioritising results at an early age (b) the "performance narrative" influencing attitudes to learning (c) the "performance narrative" reducing enjoyment of competition.

Junior tennis players prioritise results at an early age

Junior tennis players are not non-thinking pawns, who blindly attend competition oblivious to the system in which they compete. The participants in this study were aged between 11 and 13 and all perceived that results were important so they could gain acceptance into the highest graded competitions. I asked the players what kind of goals they set for themselves in tournaments, James said: "I just want to win". When I probed further and asked if there were any other performance goals for his competition, James replied "no just win". Understandably, wanting to win comes high up the list of goals for an 11 year old, in a 1 v 1 sport like tennis. When I asked James if winning was a goal he had set with his coach, James answered "no but I have to win don't I. If I want to get back into the nationals I have to keep winning".

A similar pattern emerged in conversations with all 4 participants. Responses began by describing 'wanting to win' but as conversations progressed the message moved to 'having' or 'needing' to win. For example, Lucy said "yeah, obviously I want to win. That's what tournaments are about aren't they". A positive and desirable learning outcome of competitive junior sport is a healthy attitude to competition that promotes trying your best, learning, performing well, and wanting to win. However, with each interview conducted it was clear that the participants were hyper-aware of perceived negative outcomes from losing and their focus became rankings, selection, and acceptance into competitions. Lucy said: "I've done really well recently, but now I need to keep winning because I don't want to go backwards". Consistently, the participants associated their progress in tennis with ranking and acceptance into high graded competition rather than skill acquisition. All 4 respondents competed at top national and Tennis Europe level, and they were fluent in describing the competition structure and how each event affected their self-perceived standing in tennis. Sam explained his tournament schedule for the summer: "I played some grade 3's at the start of the summer to get some wins and some confidence. Then I've got a couple of Tennis Europe events, so I can relax and enjoy them. Then I'm back for the nationals and I need to do really well there". I asked Sam why he thought he 'needed' to do 'really well', he replied: "Everyone knows who should win, so if you lose to certain players, people will make fun of you".

Sarah described similar attitudes to the other participants, saying: "Looking at all the rankings online and everyone's points, I need to get to the semi-final of my next tournament to get into the top 20. That was my goal at the start of the year, so I really need to do it".

The evidence strongly suggests the participants were overly results focussed for players so young. Social comparison based on internet research of other players and their own ranking strongly influenced the participants motivation to compete. In the junior context, competition must be a source of enjoyment, practical application of skills, and learning for personal development. However, the responses implied the main motivator to compete was 'winning'.

The "performance narrative" influences attitudes to learning

Skill acquisition is a key area of the coaching process and there will inevitably be occasions when coaches ask their players to perform new or challenging skills in competition. Applying new or refined skills in the pressure of competition is an important part of the development process because players gain valuable feedback from competition which informs their training.

Applying a new skill under pressure, whilst fearful of getting things wrong is challenging for most people. More specifically, asking an 11 year old tennis player who feels like they 'need' to win every match they play, can be an overwhelming prospect. James said: "My coach is telling me not to push the ball back and to be more aggressive, but I can't do that against xxx (player). I can't lose to him". The participants were pre-occupied with the outcome of matches and if they believed following an instruction would increase the chance of losing, they admitted to not doing what their coach asked. Lucy shared a similar experience to James, saying: "There are some matches I'm happy to listen to my coach and come to the net, but not when I'm expected to win. I can't do it in the early rounds because I can't lose to the weaker players. James and Lucy both described picking and choosing when they would listen to their coaches. Only when James and Lucy perceived there was nothing to lose, would they feel free to do what their coach wanted. However, there were matches they chose not to listen because they were pre-occupied by 'I can't lose'.

Keeping youngsters focussed on their personal development through tennis is a challenging prospect. Players can easily check results and compare themselves with others on websites and social media. Sarah described the effect that comparison to others had on her in competition: "I tried too hard today and I was so tight. I felt like I had to win no matter what. xxx (player) posted the other day she won a Tennis Europe. I guess I felt like I had to win to keep up with her. It's a good job my coach didn't watch because I didn't stick to my goals". I asked Sarah why she didn't stick to her goals, and she replied "I just wanted to win so much. I couldn't lose that match".

The participants all described struggling to follow coaches' instructions in competition in favour of doing whatever they could to win. Players who consistently play matches 'needing' to win and feeling scared of losing are less likely to try new things because they feel uncertain about the outcome. This can have a negative impact on their long-term development in tennis, due to a sustained unwillingness to try new things, gain feedback from new experiences, learn, and adapt.

The "performance narrative" reducing enjoyment of competition

Throughout the interviews, all 4 participants responses consistently referenced the theme of 'winning'. It must be acknowledged that 'wanting to win' is a healthy and desirable outcome of positive youth development, but there was a unanimous trend for the participants to shift from describing 'wanting' to win, to 'needing' to win. For example, Sam said: "I've got to win to stay on the pathway and get into all the big events". Sam's response summarises the pervading attitude throughout many of the responses.

The aim of this paper is not to denigrate 'wanting to win' and it is a shared belief that wanting to win is a positive trait. However, the attitudinal shift from 'wanting' to win to 'needing' to win must be acknowledged as a less desirable outcome of the competition system due to the potentially damaging affect it has on youngsters' attitudes to learning and enjoyment of competition.

I asked each participant during interviews if they enjoyed competitions. Sam said: "No not really. They are only fun if you win". Sarah said: "No they aren't fun. When you arrive, you feel the atmosphere". Lucy said: "I love tennis, I love training, tournaments aren't fun. But if I win, I'm happy". James said: "I like playing abroad. That's good fun because you don't really know anyone and it's quite exciting". I asked James if he enjoyed tournaments in the UK, he replied: "They are less fun because there is so much pressure to win". The evidence illustrates the performance narrative influencing the participants enjoyment of competition. An issue of continued concern must be the impact this may have on the long term development of the participants in this study.

DISCUSSION

The data in this study illustrates that junior tennis players are influenced by the "performance narrative". There are three main findings from this paper.

First, the findings of this study add to the work of Lauer et. al., (2010) and Douglas and Carless (2009 & 2012). Early specialisation in tennis and sustained participation in a competition system increases the importance young tennis players place on winning. Without access to alternative narratives to understand their participation in tennis, young tennis players use the "performance narrative" to make sense of their world and focus heavily on winning as a source of confidence.

Second, the findings highlight the presence of contradictory values in junior tennis (Gowling, 2019 & 2021). The junior development context focusses on the long-term development of young tennis players. A desire to access funding, gain selection for training, and compete in the highest graded tournaments interferes with desirable developmental narratives. Excessive focus on winning reduces players willingness to apply new skills in competition because of a fear of losing.

Finally, the findings confirm that elite junior tennis is a competitive environment that places a high cognitive load on young people (Wolfenden & Holt, 2005; Knight & Holt, 2014; Gowling, 2019). Excessive focus on winning creates pressure and therefore reduces the enjoyment experienced in competition. Junior tennis players require a cohesive support network to help them keep perspective on their tennis.

CONCLUSION

The findings of this research contribute to an evolving, problematic epistemology of junior tennis coaching and confirms that young tennis players become overly focussed on winning (performance narrative) and this can influence their attitude to learning and reduce their enjoyment of competition. The findings present governing bodies opportunities to inform coach education literature, and player support systems. Failure to address the performance narrative in junior tennis and prioritise developmental narratives has the potential to damage the experiences of young people's experience of tennis. Further work must be done to monitor the influence of the performance "performance narrative" on positive youth development in tennis and more can be done to address the misuse / misapplication of tournament systems that places too much emphasis on wining and rankings in the eyes of players.

CONFLICT OF INTEREST AND FUNDING

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The comparison of a top-level Japanese tennis player's serve-performance evolution between two seasons

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ABSTRACT

This study sought to determine the impact of changes in serve performance (relationship between speed, spin rate, reproducibility, and impact height) on world rankings for one top-level Japanese tennis player in 2017, when he became the All Japan Student Champion, and in 2022, when he represented Japan in the Davis Cup and won the ITF tournament (M25 Monastir: 10 Jan - 16 Jan 2022). This study clarifies the impact of changes in serve performance on world rankings in 2022. The results showed that, among the three types of serves (flat, slice, and kick), there were higher values for slice and kick in 2022 compared to 2017. Higher ball speed values were found for flat in 2022 and lower values for slice and kick in 2017. In 2022, all serve heights were higher, resulting in an increase in the flat success rate, which had the lowest reproducibility. These results suggest that longitudinal measurement and evaluation of the relationship between speed, spin rate, reproducibility, and impact height when serving is important for improving competitive performance.

Key words: serve performance, impact height, ball speed & number of revolutions, reproducibility.

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INTRODUCTION

In tennis, the serve is the only skill that allows a player to initiate play at his or her own discretion (Chow et al., 2003; Fitzpatrick et al., 2019; Gillet et al., 2009; Kovacs & Ellenbecker, 2011; Roetert et al., 2009). It is an important skill that can determine the result of the match. Tennis serve performance has been found to be greatly influenced by the racket (frame material and string tension) and player competitive level (Sato & Funato, 2020) and body composition (Brody, 1987; Colomar et al., 2022; Trabert & Hook, 1984). It is customary for studies on servers to consider the type of serve (i.e., flat, slice, and kick) the player is attempting to perform. According to Sato (2021b), the flat serve is an offensive stroke with high speed and low rotation speed. The slice rotates in the lateral direction inducing the receiver to be pushed out of the court after bouncing. The kick, also known as a spin serve, has the characteristic of bouncing high because it is a top spin serve. The rotation of the ball causes a big change after bouncing, which may lead to an error in the opponent's receiving technique, so spin is an important factor in evaluating serve performance. Studies on tennis serves also tend to use speed guns and high-speed cameras to analyze ball speed (Chow et al., 2003; Elliott et al., 2003). However, it is known that the behavior produced by each of the three types of serve is different (Sakurai et al. 2013), and since the change in bounce direction that occurs after landing could be influenced by different behaviors among serve types, we should consider the types of serves the player is trying to perform. In evaluating serve performance, in addition to the speed of the ball, ball spin rate is thought to be an important indicator, because the spin rate, which causes the trajectory of the ball to change, is the factor that induces errors in the opponent's prediction of how the ball will bounce and thus in his or her receiving skills.

In recent years, with the development of the TRACKMAN device to measure ball behavior, serve performance is now evaluated and analyzed comprehensively according to factors such as ball behavior (speed and spin rate), course, and reproducibility, and these data can be used by coaches for feedback (Murata & Takahashi, 2020; Sato et al., 2017; Murakami et al., 2016). Applying these experimental instruments, it was reported that high-quality serve can be evaluated and determined by analyzing the relationship between ball speed and spin rate (Sato, 2021b; Sato & Funato, 2020; Muramatsu et al., 2010; Muramatsu et al., 2015; Murakami et al., 2016). Sato and Funato (2020) attempted to quantify the relationship between players' competition level and serve performance in terms of serve speed and spin rate. They analyzed the data cross-sectionally by comparing the serve performance among male tennis players at three levels (i.e., professional, college student athlete, and junior athlete). They found differences in serve performance at the top level of each category, and performance could be evaluated by quantifying speed, spin rate, and the number of attempts required to make a successful serve. Expanding on this research and collecting data from wider levels, Sato (2021b), gathered serve performance data from Japanese top tennis players at various levels (including male and female professional players, student athletes, junior athletes, and wheelchair athletes) and measured the differences in serve performance (serve speed, spin rate, and reproducibility). The statistical analysis showed that players at higher competition levels tended to have a higher score for speed and spin rate in each type of serve (i.e., the male professional players' performance index was located in the upper right of the approximate curve obtained from the analysis). They also found that, for most players, the serve speed differed by serve type, ranked from fastest to slowest: flat, slice, and then kick. A rather different trend was seen for spin rate, which was highest for kick, slice, and lowest for flat). They also found that a negative correlation (or trade-off) between serve speed and spin rate for all three serve types. The results of their study were congruent with previous studies, such as Muramatsu et al. (2015). However, the significance of the study of Sato (2021b) was that they implemented a experimental data collection method. The data analyzed in Muramatsu et al. (2015) was a partial extract of the actual match and did not consider strategic bargaining in the match. In an actual game, the 1st serve is not always hit with a fast ball because players bargain with the opponent. In some cases, the 2nd serve, which requires a high success rate, is not hit with a rotating system. With regard to these issues, their studies were not strictly controlled. Judging from these previous studies, Sato (2021b) was a significant study that provided new evidence on the relationship of players' competitive level, the serve speed, and the spin rate. From the different studies, Sato (2021b) organized the "Serve Performance Evaluation Table," which quantitatively measures serve speed, spin rate, and success probability rate based on these findings.

Other than ball speed and spin rate, the impact height of the serve is also a major factor in improving serve performance, and there is a correlation between impact height and serve performance (Vaverka & Cernosek, 2013). Vaverka and Cernosek (2007) found that when the impact height increased by 10 cm from 2.7 m, which is the minimum to hit the service line with a straight ball, the landing point moved 25–30 cm from the service line toward the net for each 10 cm. Japanese tennis players (in ATP Tour Inc. 2021) tend, on average, to be shorter than the world's top tennis players. According to the ATP Tour website, concerning the height of the world's top 10 and Japan's top 10 ranked players in 2021, the average height of the top Japanese players tended to be about 11cm shorter than that of the world's top players. In this regard, a conscious approach to raising the impact point higher than now seems to be an essential task since this improvement would lead to a higher success rate and improved quality of the serve, which in turn would support Japanese players to take advantage of the game.

What was interesting about prior studies was that serve performance was compared multidimensionally (speed, spin rate, and reproducibility) between different competition levels to gain rich information about estimated serve performance for researchers, coaches, and the players themselves. Having an index of this kind will be beneficial because they can draw inferences about serve performance and learn from an objective data source. Although such cross-sectional studies are beneficial in that they provide a better understanding of players' performance level and serve performance, they did not measure serve performance at different stages in the players' career. Limited studies on the relationship between serve performance and players' competitive performance have continuously measured, analyzed, and evaluated tennis players longitudinally at two different career stages.

In this study, the serve performance (relationship between speed, spin rate, reproducibility, and impact height) of a top-level Japanese tennis player A (hereafter, Subject A) was assessed at two time points: (a) in 2017, when he became the All Japan Student Champion, and (b) in 2022, when he became a professional tennis player, represented Japan in the Davis Cup, and won the ITF Tournament. This study sought to clarify the impact of serve performance changes on performance level. Such data, together with those of Sato and Funato (2020) and Sato (2021b), provide additional knowledge, with both cross-sectional and longitudinal data, about players' competitive level and serve performance.

METHODS AND PROCEDURES

Subjects

The subject was a current Davis Cup player representing Japan, Subject A. Subject A's physical characteristics and changes in ranking are shown in Table 1. Subject A adopted the foot-up type (FU) stance technique for the lower limbs.

Table 1

The change in subject's physical characteristics and ranking.

Year	2017	2022
Age (yrs)	20	25
Body height (cm)	182.2	182.4
Body Mass (kg)	76.7	79.5
JTA Ranking*	34	12
ATP Ranking**	893	397

**JTA Ranking: Domestic ranking of the Japan Tennis Association (at the time of measurement). **ATP Ranking: International ranking of the Association of Tennis Professionals (at the time of measurement).*

Procedure

Before the experiment, the subject had sufficient time to hit three types of serves (flat, slice, and kick) as a warm-up. We asked the subject to use the racket to which he was accustomed for experimental trials. The ball used for the experiment was a Dunlop Fort (International Tennis Federation ITF Certified Ball/ Japan Tennis Association JTF Certified Ball, Pressure Rise Tennis Ball, manufactured by Dunlop). The subject was required to hit flat and kick serves toward the center (T zone), and the slice serve to the wide direction with maximum effort, and the ten fastest serves for each type were analyzed. Each serve was considered a successful trial if it landed in the target area (2 m long × 1 m wide). Reproducibility (serve probability) was measured from the start of the trial until each of the serves successfully landed in the targeted area five times.

Measurement material

We used a TRACKMAN Tennis Rader (TRACKMAN Inc), a measuring device that can track and measure Doppler radar from the launching to the landing of the ball, to measure the ball speed and the spin rate of the serve. The accuracy of TRACKMAN was examined by Sato et al. (2017), who compared the ball speed and spin rate calculated from TRACKMAN and Vicon, and the results showing a high correlation for both speed and spin rate (speed, r = 0.9969; spin rate, r = 0.9788). During measurement, the center of the TRACKMAN was placed on the extension of the center mark, 5.26 m behind the baseline and 2.65 m in height, so that the range of the doppler radar emitted could sufficiently cover the sideline of the court.

Methods used for the analysis

Ball speed and spin rate calculated from TRACKMAN were analyzed statistically using Spearman's rank correlation coefficient. We measured how the values of the speed, spin rate, and impact height of the subject's serve performance changed from 2017 to 2022 by calculating the rate of change of those values.

Ethical considerations

This study was approved by the Meiji University Ethics Review Committee (Approval No. 557). The subject was provided with written and verbal information regarding the purpose and contents of the study. It explained that the results would not be used for anything other than the purpose of this study and that participation in the experiment was voluntary. In addition, an explanation that there would be no disadvantage for not participating in this study was also included. Finally, the subject could cancel participation even during the measurement.

RESULTS AND DISCUSSION

Ball speed and spin rate

Prior research has shown that there is a trade-off relationship between ball speed and spin rate, with higher speeds resulting in lower spin rates (Sakurai et al., 2013). Muramatsu et al. (2015) also found that the higher the level of competition,

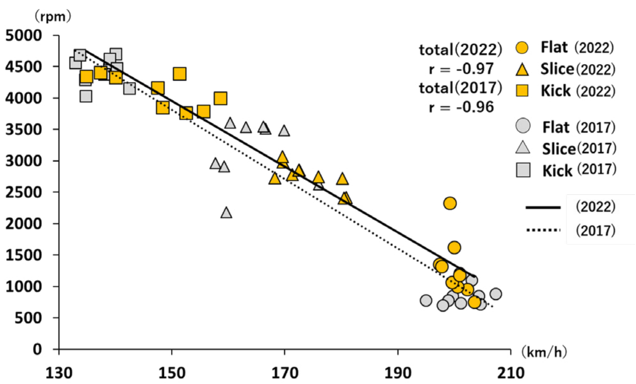

Figure 1. *The Relationship Between Ball Speed and Spin Rate (2017 vs 2022).*

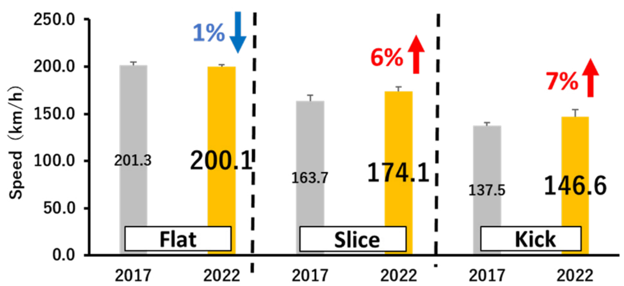

Figure 2. *The Speed (km/h) of the Serves (2017 vs 2022)*

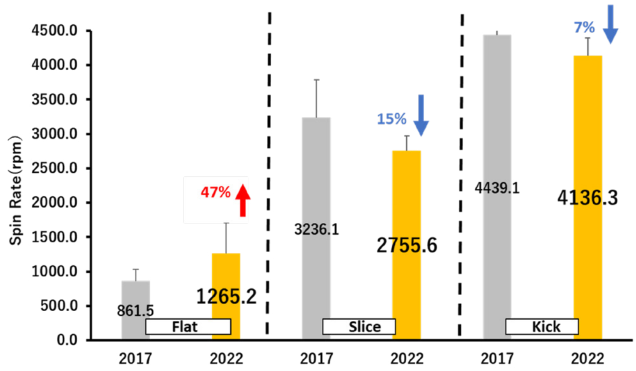

Figure 3. *The Spin Rate (rpm) of the Serves (2017 vs 2022).*

the higher the serve speed (x-axis) and the spin rate (y-axis), which were located in the upper right of the curve of the regression line. Some studies have stated that the same ball speed shows a tendency for a greater spin rate and the same spin rate shows a tendency for higher speed (Murakami et al., 2016; Muramatsu et al., 2015; Sato & Funato, 2020). However, focusing on the values of Subject A's flat serve in 2017 and 2022, we found a significant increase in spin rate (47%), while only a slight decrease in speed (1%), which indicates that speed and spin rate do not necessarily follow a trade-off relationship, which commonly occurs when evaluting serves (fig. 2, 3). This positive development may be one indicator showing higher performance for Subject A's serves (and for the flat serve in particular) in 2022 compared with 2017. The increase in spin rate for the flat serves, the so-called fastball type, affects the behavior of the ball both in the air and after it lands in the service area, making it more difficult for the opponent to hit the ball back and contributing to the server proceeding in the game favorably. Given that the approximate line in 2022 went up to the upper right location compared with that from 2017, it can be presumed that this indicates an improvement in the quality of Subject A's serves, in line with Muramatsu et al. (2015) (fig. 1). In addition, when this value was assessed using the serve rubric (3-point scale) created by Sato (2021a, b), we can assume that the improvement from a score of 2 to a score of 3 has made it possible for the subject of this study to take advantage of the game having a higher quality of serve.

Reproducibility and impact height

The relationship between ball speed, spin rate, and reproducibility is an important indicator for assessing competition level (Sato & Funato, 2020; Sato, 2021b). When looking at Subject A's impact height in 2022, we found that it was higher than in 2017 (an average increase of 5.6%) (fig. 4). In addition, in the flat serve, where the trade-off between speed and reproducibility (Chow et al., 2003) generally indicates a tendency toward lower reproducibility, the reproducibility improved from 10 serves required for a successful attempt for the serve task in 2017 to 6 serves in 2022. Vaverka and Cernosek (2013) found a correlation between impact height and serve performance, and Brody et al. (1987) stated that a higher impact height increases the opponent's margin of error. In fact, the success probability of the first serve (which is said to often be hit in a fastball type) by the two players ranked first (J.I.: Body height; 2.08m) and second (R.O.: Body height; 2.11m) in the Serve Rating calculated by the ATP Tour in 2022 was 68.8% for J.I. and 65.9% for R.O. (ATP Tour, 2022),

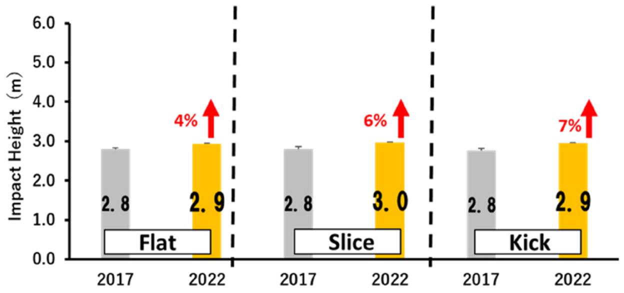

Figure 4. *The Impact Height of the Serves (m) (2017 vs 2022).*

with an average of 2.3 to 2.4 double faults per match (i.e., an extremely low probability rate). The estimated impact height is said to be about 150% of the height of the player (Whiteside et al., 2013), and because the impact height of J.I., the world's No. 1 server, is estimated to be 3.16 m, the margin of error is extremely high.

It can be inferred that an increase in body weight (+2.8 kg) brought about an improvement in overall physical performance, although there was no increase in height between the two measurement points. The leg drive during the loading phase (hereafter referred to as leg drive) resulted in a large ground reaction force (GRF; Elliott & Wood, 1983). This large GRF may have enhanced the movement linking knee flexion to jumping, resulting in a higher impact height compared to 2017. Subject A's use of FU in the lower limb stance technique is another important technique for improving serve performance among Japanese players (Konishi et al., 1997), who are generally relatively short in stature. It has been suggested that FU tends to increase vertical GRF during the loading phase and may increase impact height (Elliott & Wood, 1983). This would be one essential process to include when the change in impact height is used as an evaluation indicator following Sato (2021b) and Sato and Funato (2020), and could be a reason for Subject A's improved competition level (i.e., world ranking). Increased impact height is a major factor (Bartlett et al., 1995) in producing higher ball speed and higher serve performance. How the player uses the chain of mechanical energy to hit the ball with the racket is a major factor for the speed and spin rate of the serve. As mentioned, the minimum impact height for a straight ball to land on the service line is 2.7 m (Brody, 1987; Chow et al., 2003; Trabert & Hook, 1984), and increasing the impact height by 10 cm moves the point of impact 25–30 cm closer to the net from the service line (Vaverka & Cernosek, 2007). For Japanese tennis players, the approach to impact height is a critical issue for performance improvement. The average height of the world's top-level tennis players (ATP Ranking 1–10) is significantly higher than that of the top-level Japanese tennis players (JTA Ranking 1–10) (ATP Tour, 2021). According to Whiteside et al. (2013), the estimated 2017 and 2022 impact height for Subject A can be estimated as 2.73 m. Adding the increase in impact height (5.6%) obtained in this study, the impact height would have been raised to approximately 2.87 m. These results suggest that Subject A consciously focused on the relationship between the net and impact height, which may be a factor for the higher probability of successful attempts (Bartlett et al., 1995), mainly by strengthening the lower limb muscle groups and improving loading technique, thus leading to a higher vertical GRF than in 2017. The increase in impact height may have increased the margin of error and contributed to the improvement in the reproducibility of flat serve values (2017: 10 balls vs. 2022: 6 balls).

CONCLUSION

Longitudinal measurement and quantification of serve performance in tennis players will reveal how serve performance improvements affect competitive performance (i.e., ranking). This study sought to clarify the impact of changes in serve performance on world rankings by comparing and examining the speed, spin rate, reproducibility, and impact height of a Japanese top-level tennis player in 2017 and 2022. There are four key findings. First, higher values were found for slice and kick in 2022 compared to 2017. Second, higher values were observed for speed in 2022 for flat and lower values for slice and kick compared to 2017. Third, higher values for impact height in all three serve types were observed in 2022 compared to 2017. Fourth, high reproducibility (based on the number of attempts required for success) in the flat serve, together with an increase in speed and spin rate, was observed in 2022, although this type of serve is highly influenced by the trade-off relationship between speed and spin rate. These results suggest that longitudinal measurement and evaluation of serve performance (speed, spin rate, repeatability, and impact height) is important for improving competitive performance.

LIMITATIONS AND FUTURE ISSUES

This study examined the relationship between serve performance and world ranking by focusing on the serve performance of a Japanese top-level tennis player (Subject A) in 2017 and 2022 in terms of four variables: speed, spin rate, reproducibility, and impact height. In addition to the measurements used in this study, future studies could also analyze movement, body composition (muscle length, thickness, body fat percentage, etc.), and the energy flow generated by the upper and lower limbs to contribute to further improvement of athletic performance.

CONFLICT OF INTEREST AND FUNDING

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

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RECOMMENDED ITF TENNIS ACADEMY CONTENT (CLICK BELOW)

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Development of reaction times in young tennis players using the SensoBuzz application

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ABSTRACT

This study is aimed at analyzing young tennis players through an evaluation of the simple reaction times (RTsS) and complex reaction times (RTsC) using the SensoBuzz console, equipped with a chronometer, connected to a release button, three push buttons and two conductance platforms. The SensoBuzz console was used for a first evaluation of the simple and complex reaction times of the young tennis players and a subsequent verification, after three months of training. Following the first measurement, the subjects trained weekly with the help of the SensoBuzz application installed on the coach's device (tennis coach and/or physical trainer) diversifying the workouts on reaction times. After three months of training, the results showed shorter reaction times following the training with the SensoBuzz application compared with training without the SensoBuzz application. More specifically, we observed an effect on simple reaction times when comparing players' training once per week and players training six times per week.

Key words: Tennis, reaction times, cognitive, SensoBuzz

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INTRODUCTION

The reaction time is a special coordination capacity, which allows everyone to respond to a stimulus in the shortest possible times (Mead et al., 2000; Jui-Hung Tu et al., 2010; Emre et al., 2010; Uzu et al., 2009). The reaction time is defined as "simple" when a single signal corresponds to a single predetermined action; it is defined as "complex" when the signals can be different, and the response can be chosen among many possible (Buzzelli, 2021; Zajdel & Nowak, 2007; Buzzelli, 2020).

In tennis sport, the reaction times are shorts, especially in the response to the service, which has become more and more a fundamental shot since the speed of the ball in the game phase has had a substantial increase. This is certainly due to the development of new materials for the rackets, today built with increasingly lighter and more performing materials, developed especially for the prevention of injuries. Moreover, a more accurate and specific physical preparation, associated with the nutritional part, has undoubtedly contributed to an increase in the speed of the ball (Senatore & Cannataro, 2019).

In tennis sport, being able in a few milliseconds to prepare, hit the ball and direct it to a specific point of the opposite half of the court, is essential to put the opponent in difficulty. Precisely in this case different coordination skills come into play, also associated with attentional and cognitive aspects, which should be trained daily, to improve the ability to react.

This study analyses young tennis players through an evaluation of simple reaction times (RTsS) and complex reaction times (RTsC) with the aid of a SensoBuzz console.

Knowing that the best way to detect the simple reaction times is to use a handpiece equipped with a release button (Buzzelli, 2021), to allow a correct comparison of the data, the pressure key system was used for the detection of the complex reaction times, which consists of a stopwatch, connected to a release platform, three push buttons and two conductance platforms. This device was used before and after the evaluation tests. Young tennis players have been able to diversify the attentional-cognitive-motor training on reaction times, extremely important in modern tennis. In fact, in addition to the initial tests, an application of the SensoBuzz was used, to train attentional-cognitive-motor training on the tennis court.

To the best of our knowledge, no scientific articles have focused on how to train reaction times in tennis, especially in the youth field, using the described tools.

TOOLS AND METHODOLOGY

Subjects

60 subjects were considered, including 30 males and 30 females, aged between 10 and 16 years. The subjects tested trained from 1 to 6 times a week (1 hour and 30 minutes per training session). Each of them presented a ranking between 3.1 and 4.NC of the classification of the Italian Tennis Federation.

Tools

Two scientific technological tools were used:

1. The SensoBuzz console is a system designed by Salvatore Buzzelli, which evaluates simple and complex reaction times. It is equipped with a chronometer connected to a release button, three pressure keys and two conductance platforms (see Fig.1). The in-house software measured simple reaction times (RTsS) and complex reaction times (RTsC). To evaluate simple reaction times, the visual stimulus used was the yellow color and when the color appeared on the led installed the top left of the console, the young tennis player had to release the button of the handpiece. On the screen placed at the top right of the console was displayed the corresponding reaction times registered between the visual stimulus and the release of the handpiece. To evaluate complex reaction times, the visual stimuli used were three colors: red, yellow, green; the auditory stimuli were two: high and low tone. The tennis young player after receiving the visual and/or auditory stimulus were instructed to press either the press keys on the console, or one of the two conductance platforms located to the right and left side of the young tennis player. This tool was used for a first evaluation of the simple and complex reaction times of the young tennis players and a subsequent verification, after three months of training.

Figure 1. *The figure shows the SensoBuzz console used to evaluate simple and complex reaction times.*

2. The SensoBuzz application is a tool designed to train reaction times in all sports. It is designed and built by Salvatore Buzzelli. This application is dedicated to the analysis and development of some coordination and sensorimotor skills, focusing on attentional skills. Available on devices with Android and iOS systems, it allows to train the reaction times through visual and auditory stimuli provided randomly. The visual stimuli are composed of: 4 colors (green, yellow, red, blue), 4 arrows (top, bottom, right, left), and 4 symbols (x, +, ?, #); the auditory stimuli are two: high and low tones. For each visual and/or auditory stimulus, a motor task is performed. For example, when the green color appears on the device, the young tennis players have to run forward for 3 meters, when the blue color appears on the device the young tennis player have to run to the right for 3 meters, when the device emits a high tone, the young tennis player have to run back three meters.

Methodology

For each subject we collected anamnestic (personal data) and anthropometric data (weight and height). We then proceeded with the measurement of the simplex and complex reaction times through the SensoBuzz console. The simple reaction times was detected with the use of a handpiece equipped with a release button (normally closed circuit).

Specifically, for the detection of the simple reaction times, it was asked to hold down the button on the handpiece, to release it as soon as the stimulus was received and to re-enter it immediately after. This made it possible to process the reaction times by the instrument and to view it in real times on the display of the SensoBuzz console.

The complex reaction times was always detected with the use of the SensoBuzz console, on which three pressure buttons of different colors were positioned and to which two platforms, also of different colors, were connected to the ground (normally closed circuit).

Each subject was asked to react to stimuli either with the use of the hands (in the simple reaction times) or with the use of the feet (in the complex reaction times).

To measure complex reaction times, we used different colors corresponding to three visual signals and platforms of two different colors, each placed on the sides of the examiner's feet.

The number of stimuli emitted was five for the simple reaction times and ten for the complex reaction times.

Three months after the first training session, all subjects were re-examined following the same procedure.

Based on the initial evaluation, subjects were distributed in three study groups and one control group:

- Group 1: 10 subjects trained 1 time a week for 20 minutes with the SensoBuzz application.
- Group 2: 10 subjects trained 3 time a week for 20 minutes with the SensoBuzz application.
- Group 3: 10 subjects trained 6 time a week for 20 minutes with the SensoBuzz application.

- Control group: 30 subjects trained 6 time a week for 20 minutes without the SensoBuzz application.

During each training session, the study groups used the SensoBuzz application, installed on the coach's device, while the control group trained without the use of the SensoBuzz application. After three months of training, we evaluated the reaction times with the SensoBuzz console.

All subjects were tested in indoor courts, with an average atmospheric temperature of 8° C. Each training session provided four young tennis players and an expert (tennis coach and/or physical trainer) on the court. During the weekly training sessions, lasting 1 hour and 30 minutes, the young tennis players trained for about 20 minutes only on reaction times. The trainings were carried out with random exercises by both the tennis coach and the physical trainer and took place on a single surface, fast in resin glass, in order to have as a parameter a single reference surface.

ANALYSIS

Data were analyzed using the following measures: RTsS, RTsC, RTs control group.

We performed 4 different analyses.

In order to pinpoint a reduction in reaction times due to the use of the SensoBuzz application, in the first analysis we compared RTsS registered from players that used SensoBuzz application versus RTs of the control group (training without the use of the SensoBuzz application).

Similarly, the second analysis compared RTsC registered from players that used SensoBuzz application to RTs of the control group (training without the use of the SensoBuzz application).

Differences between RTsS and RTs control group, and RTsC vs. RTs control group were highlighted using paired sample t-tests.

The third and fourth analysis were performed aiming to demonstrate an effect of training due to the SensoBuzz application. Thus, simple and complex RTs were analyzed for different Types of Training (one a week, three times per week, six times per week). Differences in RTsS and RTsC per Type of Training (one time per week, three times per week, six times per week) were entered separately into an Analysis of Variance (ANOVA) with Type of Training as between-subjects factor. Post-hoc analyses were conducted via pairwise comparisons (t-tests). We used Holm correction for all comparisons.

RESULTS

RTs simple versus RTs control group

The paired t-test indicated a significant difference between RTsS and RTs control group ($p<.001$) showing shorter RTsS compared to RTs of the control group.

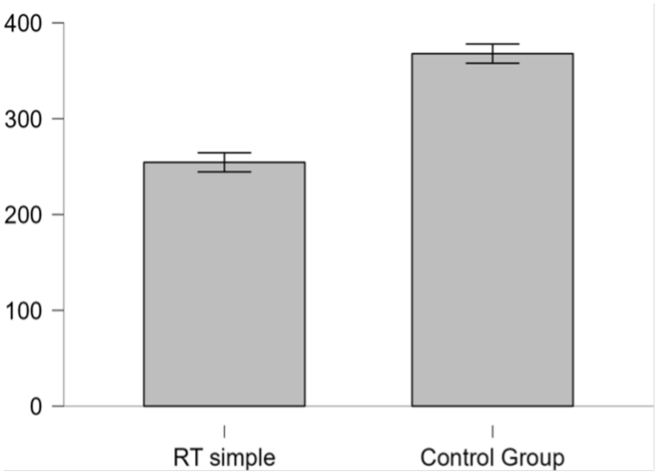


Figure 2. *The figure shows the average of RTsS measured from the study groups compared to the average of RTs measured from the control group. The bars represent the standard deviation from the average. The y-axis displays RTs in ms.*

The paired t-test indicated a significant difference between RTsC and RTs control group ($p<.001$) showing shorter RTsC compared to RTs of the control group.

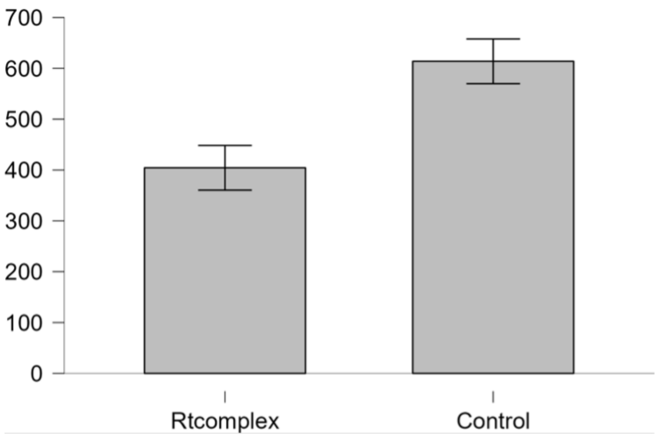


Figure 3. *The figure shows the average of RTsC measured from the study groups compared to the average of RTs measured from the Control Group. The bars represent the standard deviation from the average. The y-axis displays RTs in ms.*

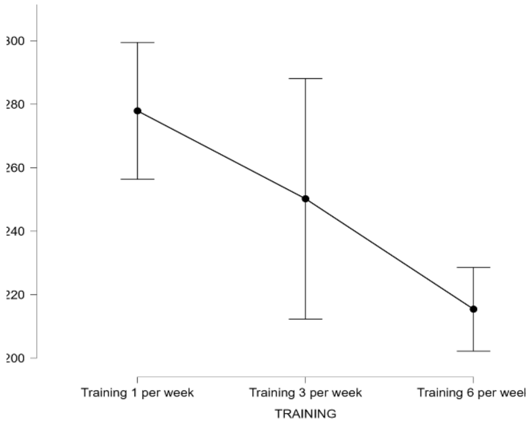
RTsS and RTsC for different training

The ANOVA indicated a significant main effect of Type of Training [$F(2, 27) = 10.080$, $p < .001$], a main effect of RTs [$F(1, 27) = 227.676$, $p < .001$], the interaction RTs*Type of Training [$F(2, 27) = 0.586$, $p = .564$] was not significant.

To assess differences between RTsS and RTsC, and between Types of Training post hoc comparisons were performed. We observed a statistically significant difference in the RTsS compared to RTsC ($p<.001$) with shorter RTsS compared to RTsC.

We also observed significant differences between all Types of Training (Training one time per week vs. Training three times per week, p =.048; Training one time per week vs. Training six times per week, p <.001; Training three times per week vs. Training six times per week, p =.048) showing shorter RTs in players that trained six times per week compared to players that trained one and three times per week.

Additionally, post hoc comparisons were performed per Type of Training across different RTs (simple, complex). The results highlighted significant differences in RTsS between players that trained one time per week and players that trained six times per week (p = .002) showing shorter RTs in the second compared to the first. No other significant differences were observed.



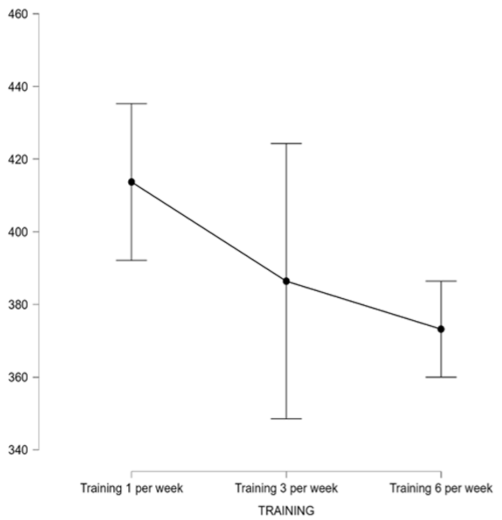


Figure 4. *The figures show the comparison of the RTs simple (left) and RTs complex (right) measured during the various Types of Training (Training one time per week, Training three times per week, Training six times per week).*

CONCLUSIONS

The present study demonstrates, for the first time ever, that training with SensoBuzz application results in shorter reaction times in young tennis players compared to training without SensoBuzz application.

Moreover, different reaction times were associated to the amount of training (one, three or six times per week) with the SensoBuzz application showing faster RTsS in the players that trained six times per week compared to those who trained one and three times per week. The use of SensoBuzz application seems to do not influence RTsC in any of the Types of Training tested in this study.

Therefore, more young tennis players train with the SensoBuzz application shorter the simple reaction times measured.

We hypothesized that young tennis players using SensoBuzz application could shortened their RTs especially in response to the service of the opponent leading thus to an increase of speed, effectiveness, technic and tactic. Future research may address this point more specifically.

Modern tennis is more dynamic and faster compared to the tennis played years ago. Thanks to the training described in the previous section, players may increase their effectiveness and awareness due to an improvement of essential coordination capabilities: the ability to react (more assimilable in adolescence than in adulthood).

Finally, the use of SensoBuzz application during training results in boosted sensory and cognitive activations also due to the processing of visual and auditory stimuli which in turns led to an enhancement of attentional and motor responses, motivating the player to improve daily.

CONFLICT OF INTEREST AND FUNDING

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

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COACHING & SPORT SCIENCE REVIEW

The incidence of injuries across various tennis surfaces: A systematic review

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ABSTRACT

Tennis players' joints are subjected to enormous loads, with supraphysiological stresses generated at the shoulder and elbow hundreds of times per match. Chronic injuries typically concern the upper extremity while acute injuries typically affect the lower extremities. The type and frequency of injuries have also changed as a result of advancements in equipment and playing surfaces. Top athletes and coaches need some understanding of how the playing surface affects tennis performance. Thus, the purpose of this review is to provide an overview of the most recent research on injuries and playing surface effects in tennis. The main aim of this study was to ascertain whether there is a difference in the incidence of tennis injuries between the four most popular court surfaces, including clay, hard, grass and concrete. Tennis court surfaces have been identified as a factor that influences the occurrence of injuries. The evidence strongly suggests that the surface is a significant component in injury causation and varying surfaces have been found to have considerably different injury rates. A systematic search of published reports was conducted in four electronic databases from 2010 to discover relevant articles relating to tennis injuries and surfaces.

Key words: tennis injury, surfaces, incidence, elite athletes.

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INTRODUCTION

Tennis is a well admired and frequently practiced racquet sport (Girard et al., 2007). While playing tennis, the joints of the body undergo larger physiological forces (Dines et al., 2015). The muscle segment and force associated by the kinetic chain starting from the feet moves to knee and from there it moves to shoulder and elbow, terminating at the wrist to the racquet. Serving is the most intensive shot of the play (Dines et al., 2015). During serving the greatest muscle activation occurs in shoulder and forearm. The tennis serving is divided into 8-stage model involves three distinct phases. Preparation, acceleration, and follow-through. The phase reflects the distinct dynamic functions of the serve: Start, Release, Loading, Cocking, Acceleration. Contact, Deceleration and Finish (Kovacs and Ellenbecker, 2011). The physical demands of the sport place unique demands on the musculoskeletal system. Acute injuries, like ankle sprains, are more frequent in the lower extremity, whereas chronic overuse injuries, like lateral epicondylitis, are more prevalent in the upper extremity in recreational players and shoulder pain is more prevalent in high-level players (Abrams et al., 2012).

According to research, the injuries that occur while playing tennis have been linked to many internal and external factors. The nature and rate of tennis injuries can differ depending on the various surfaces where the sport is played upon and the equipment used in the sport. The three classic surfaces are hard, clay and grass courts. The four Grand Slams are played on different court surfaces: the Australian Open on Plexicushion Prestige hard courts, Roland Garros on clay courts, Wimbledon on grass courts, and the US Open on DecoTurf hard courts (Anna et al., 2019).

The physical demands of the sports combined with the volume of play can result in musculoskeletal injuries. Numerous studies have reported on the frequency and prevalence of injuries in tennis (Abrams et al., 2012). Tennis involves high aerobic as well as anaerobic energy system requirements throughout the game play (Dines et al., 2015). Tennis matches frequently last longer than one hour, occasionally even longer than five hours (Michael et al., 2010). The rally can last between 6 to 10 seconds, while grass courts and fast courts both have shorter rally times than clay courts do. The length of the rally is substantially longer in the women's game than the men's when professional tennis players are playing on clay (Torres et al., 2011). Different ball speeds and bounces have an impact on the ball-surface interaction, which in turn affects the style of play. Clay is called a sluggish surface because when the ball touches the ground it undergoes a greater friction with the surface, so the speed of the ball gets reduced. On hard courts, the faster the ball travels, the more force is applied to the upper extremity. (Martin and Prioux, 2016). The loading conditions of tennis players are impacted by complex dynamic movements (side jumping, cutting, and braking) (Orendurff et al., 2008). Friction between the shoe and surface is influenced by the intensity of these forces as well as other factors, such as surface roughness (Clarke et al. 2012).

Professional and competitive tennis players nowadays train and compete in different sporting surfaces. Because of the calendar year (Martin & Prioux, 2016). They compete and practice in different surfaces as well (Martin et al., 2011) 210 diverse court surfaces were approved in 2011 by the International Tennis Federation (ITF) (Martin & Prioux, 2016). On each of these surfaces the bounce of the tennis ball is different which may cause a change in game style from the players, and therefore the results (Martin & Prioux, 2016). The ITF classifies field surface into classes by structure and by court speed rating (CPR). Two key boundaries are utilized to decide the properties of CPR: their frictional coefficient and restitution coefficient (Martin & Prioux, 2016). Due to the frictional and stress absorption qualities of these courts, the hard court has a higher injury rate than the clay court (Pluim et al., 2018). The available data which can be used for validation is however opposing the above fact. The proper conditioning for tennis will strengthen the kinetic core and will ensure healthy play while minimizing injuries (Dines et al., 2015). High frictional surfaces cause longer braking and relevant conditioning to reduce the heavy loads on the joints has been proposed. With the greater pace in serves and the other shots of tennis, the loading in the joints of the upper limb increased drastically. Furthermore, the stress in the joints of the lower extremities increased because of the strong flexion and extension of the lower extremity, resulting in both upper and lower limb injuries (Dines et al., 2015).

Therefore, tennis players are vulnerable to several injuries (Dines et al., 2015). Acute injuries appear to harm the lower extremity; the upper extremity is typically implicated with chronic conditions (McCurdie et al., 2017). Several researchers found that lower limb injuries are the most common in tennis, with upper extremity and trunk injuries following in prevalence (Dines et al., 2015). Ankle and thigh are the frequently injured lower extremity joints, whereas the shoulder and elbow are the most damaged upper extremity joints and the lower back is the most injured trunk area. The most frequent forms of injuries, followed by inflammation and sprains, were muscle strains (Dines et al., 2015). The various tactics adopted by Players are likely to impact the occurrence of injuries because of changes in the playing field. Because lower limb injuries account for more than half of all tennis injuries, it is vital to think about what causes them (Pluim et al., 2018). Epidemiological studies have backed up and suggested that surfaces that allow for smooth sliding and slipping have a lesser risk of causing injury. Allowing sliding on the court reduces the strain on the lower extremities.

OBJECTIVES

Primary objective is to study the incidence and type of injuries across different tennis surfaces. In order to ascertain whether there are any differences in the occurrence of tennis injuries across the four most popular court surfaces among professional athletes. Condition or domain being studied: Any injury that occurred while playing or practicing on the various sporting surfaces of tennis. Participants included all professional and elite adult tennis players. Exposure to the various sporting surfaces (clay, hard, grass and concrete). Injury rates will be calculated for match play, training, and total play, and reported as the number of injuries per 1000 playing hours.

There will be no comparator and the outcome is Upper limb, trunk, as well as lower limb injuries developed during competition and practice across the various tennis surfaces.

METHODS

Information sources and literature search strategy

We conducted a literature search to find potentially pertinent articles published after 2010. This systematic review was conducted according to the framework provided in the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-analysis). Using research questions developed in the Patient Problem, (or Population) Intervention, Comparison or Control, and Outcome (PICO) methodology. A computerized English language literature search of the grey literature: The research was done using Google Scholar and electronic databases such as PubMed (MEDLINE), Scopus, Cinahl, and Web of Science. Combinations of Mesh terms were applied, with the aim of identifying hidden studies. Articles are organized using the reference management software package, Rayyan, a web and mobile application for systematic review. The following search syntax, which uses Boolean operators in titles, abstracts, and keywords of indexed articles, was used to find relevant information relating to tennis injuries, epidemiology, and incidence: ("epidemiology*" OR "incidence" OR "injury incidence" OR "prevalence" OR "injury rate*" OR "risk factor*" OR "injury surveillance" AND (("Hip Injuries" OR "Back Injuries" OR "Foot Injuries" OR "Ankle Injuries" OR "Wrist Injuries" OR "Tendon Injuries" OR "Leg Injuries" OR "Knee Injuries" OR "Hand Injuries" OR "Forearm Injuries" OR "Athletic Injuries" OR "Abdominal Injuries" OR "Rotator Cuff Injuries" OR "Shoulder Injuries" OR "Cumulative Trauma Disorders" OR "Anterior Cruciate Ligament Injuries" OR "Reinjuries" was conducted.

Study selection

Research studies were included if they accessed the incidence rate or prevalence or epidemiology of injuries with relation to different tennis surfaces. If the title and abstract did not provide enough information to determine whether the article was relevant to the review, the entire article was obtained and read. This allowed us to see if the paper met the primary criteria for inclusion. Letters to the editor, conference abstracts, and literature reviews were all excluded from the study.

Eligibility for inclusion and exclusion

The studies will be selected based on the population, exposure, comparison, and outcomes criteria. All three authors agreed on the inclusion and exclusion criteria. Following the initial study selection process, three authors independently completed a blinded standardized eligibility assessment by screening the titles and abstracts. The literature had to meet the following inclusion criteria to be considered.

Inclusion and exclusion criteria

To be considered for inclusion in this review, studies had to meet the following inclusion criteria. Articles that met the following criteria were included: (1) Articles addressing incident rate tennis injuries, in relation to various sporting surfaces and activity level in athletes- Recreational/Elite, (2) Study design: Should be primary observational studies and Primary observational studies, Cohort or Descriptive Epidemiological studies usually report incidence rates of injuries. To enable comparison and analysis, these two study designs are selected. Excluding reviews and RCTs (Randomized control trials). (3) Study participants included all professional and elite adult tennis players, (4) They had to be published in English. As a greater amount of studies has been published in English both the authors understand only that language, articles which are published only in English will be included and (5) Years Considered: January 2010- November 2020- Last 10 years. Only studies published in the last decade were considered because the game of tennis has changed. (6) Published articles, (7) any tennis surface (e.g.: clay, grass, hard and concrete courts) and excluded Injuries reported not in relation to tennis surfaces, (8) Comparison between different tennis surfaces, (9) Must report incidence of injuries (upper or lower extremity or both).

RESULTS

PRISMA chart

After searching five databases, on the search Based strategy, a total of 7196 articles were discovered through Rayyan software (https://rayyan.ai) which is formerly (https://rayyan.qcri.org). Figure 1 depicts the process of selecting and screening articles in more detail.

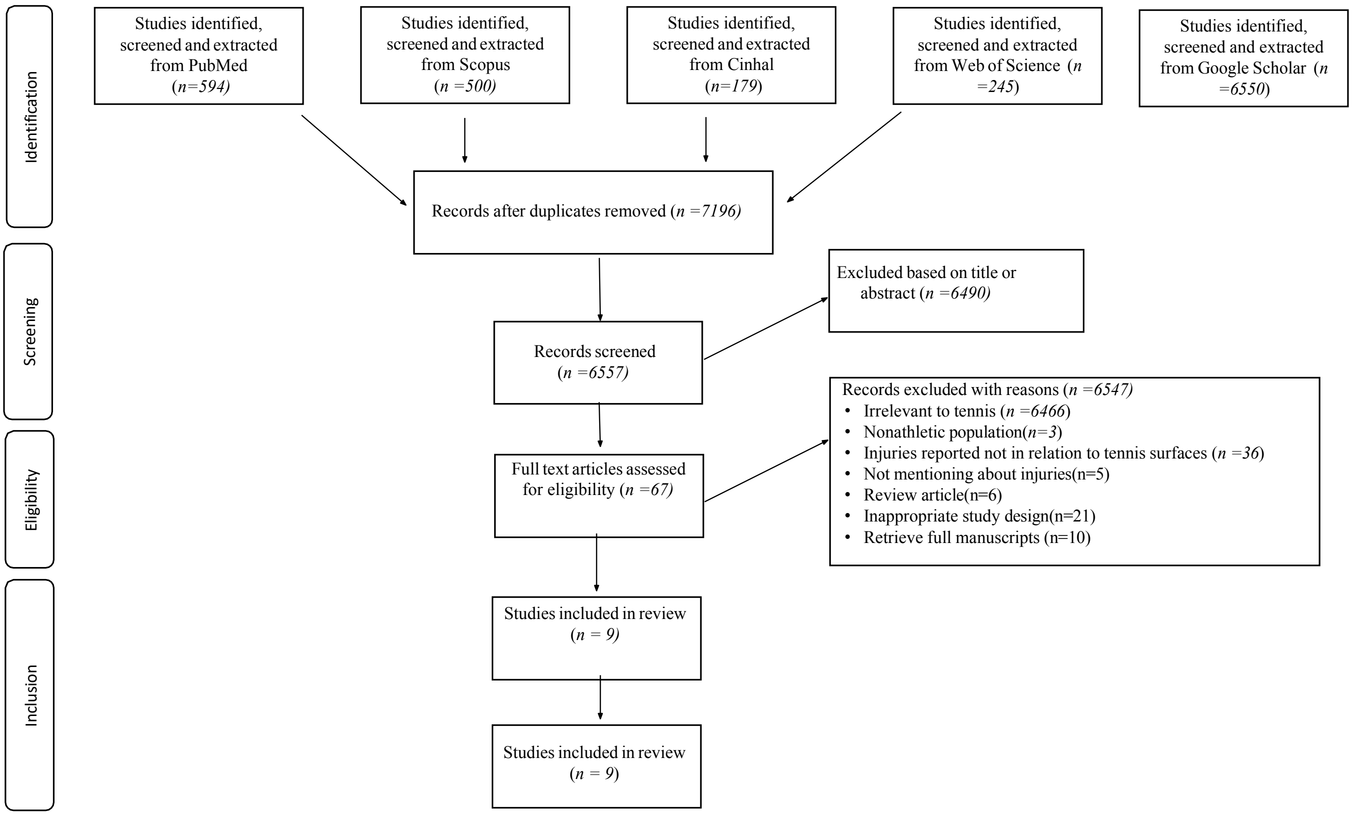

Figure 1. *PRISMA flow chart for the article inclusion process.*

Data extraction

Data was extracted from the 9 studies. The following data was extracted from the included studies for data extraction: Authors and year of publication (Study ID), DOI, Publication Type (e.g., Journal article, letter, abstract), Country in which study was conducted, Funding Source, Ethical Approval,Reference citation, Type of Study, No. of participants (total number and number of male and female players), Duration of the study, Type of game session, (competitive / practice) name if competitive, Type of surface, Type of Intervention (I), Type of Outcome (O), Description of the Population (From which study participants are drawn), Criteria for inclusion, exclusion, method, and allocation units (individuals/clusters/groups), Age (Mean/Median/ Range), Participant Characteristics (Height, weight and Body massand other details if mentioned), Aim of the study, Objectives of the study, Sampling Technique, Study Start Date, Study End Date (if any cohort), In results section mentioned the types of injuries, Incidence of injuries reported, Statistical analysis used and the appropriateness of these methods, analysis method used to measure within group differenceand statistical analysis value.

Data collection process

The form for data extraction for each included study thatconsisted of all the required contents about the context of the study, information on the study design, study methods, Characteristics and size of the sample, source of the study participants, attributes of the exposure, outcome definitions and analyses used. Since this study emphasized on the incidence rate of injuries related to different tennis surfaces was extracted from the individual studies in order to understand the determinants better.

The following is a summary of the study's features. Characteristics and results of included study.

Table 1

Summarises the percentage of the incidence of injuries in surfaces.

Study	Incidence Rate	Surface the injury been reported
1	Total of 700 injuries occurred at a rate of 20.7%	Grass Courts (throughout the competition season, switching between surfaces)
2	50% to 65% for men. 60% and 70% for women	Hard, Clay and Grass court
3	Less than 50%	Clay and grass court
4	Men and women are respectively- 80%	Clay and hard courts
5	57% of the injured players	Clay and hard courts

The results of the study indicate that there were few differences in the rate of injury among the four different court surfaces examined: More injuries to lower extremities on hard courts compared to clay, being 56 % and 38 %, respectively. Male athletes, on the other hand, had a higher likelihood to sustain an injury when playing on hard courts than when on the clay ones (Hartwell et al., 2017). The most reported location for males was found to be lower back injuries. The most pervasive injury location for women was the thigh, which included both quadriceps and hamstring injuries.

However, players who played on multiple surfaces had a higher injury prevalence, particularly of overuse injuries, than those who primarily played on one court surface.

Compared with the other court surfaces, there was a higher prevalence of lower limb overuse injuries when playing on hard court (Pluim et al., 2017). This might be because they played more tennis each week, putting more physical strain on their bodies, or because players do not have enough time to become used to new surfaces, which puts more stress on their bodies (different ball bounce and ball speed, different sliding characteristics). Which allow for fast changes in direction and high acceleration and deceleration, are likely to put more pressure on muscles and tendons.

Athletes who played on surfaces that allowed for controlled sliding, such as clay, experienced much lower "pain and injury" compared to athletes who played on surfaces that do not allow for controlled sliding, including concrete. Clay courts have been found to have lower injury rates than hardcourts, which is thought to be due to lesser friction (Starbuck et al., 2015). Women have reported a higher injury rate on courts of clay, when compared to hard courts (Hartwell et al., 2017). In comparison to clay and hard-court sports, trunk injuries are more common on grass courts. Compared to hard courts, clay courts have been reported to have lower injury rates. This is likely because these surfaces have less frictional resistance. The risk of lower back injuries was influenced by the playing surface (Kryger 2014). As opposed to clay courts, hard court surfaces substantially more frequently caused injuries to women. For both women and men, trunk injuries were much more common on grass than on hard courts (Kryger 2014).

DISCUSSION

The major goal of the current research was to identify the occurrence and types of injuries that occur across various tennis surfaces. Tennis is a sport in which players perform rapid, intense, and repetitive start-stop motions, direction changes, sprinting, and sliding side-to-side type of movements. Injury rates are impacted by the nature of the sport as well as the impact of different surfaces. The second objective of review

Table 2

Summarises the characteristics of the 9 papers included in this study.

Study	The game session type (competitive / practice)	No. of participants/duration of the study	Population	Surface
1	Competitive - Wimbledon	From 2003 through 2012, 10-year span	Elite tennis players	Clay courts
2	Competitive	10 tennis players	Elite tennis players	Clay courts
3	Competitive - The Australian Open, French Open, Wimbledon, US Open	For males, 2001-2012. For women, 2003-2012	Elite tennis players	Hard, grass, and clay courts
4	Competitive	10 (7males, 3 females) Experienced male tennis players	Elite tennis players	Hard, clay, and grass courts
5	Competitive	Records of men's and women's tournament from USTA Pro Circuit of the year 2013	Professional tennis players	Clay, hard
6	Competitive	65 players [40 boys,25 girls]	Elite junior players	Clay and hard court
7	Competitive level	8 tennis players University level (5 males, 3 females)		Hard, clay court
8	Competitive	10 tennis players (9 men, 1 women)	Elite junior players	Clay court
9	Competitive tennis players	7 players (5 males, 2 females)	Elite junior players	Hard court, artificial clay

is to point out which types of injuries are common on various surfaces. The finding of this research indicates the variations in the occurrence of the injuries between the courts. In today's professional tennis season, players must adjust to each court surface within a relatively short period of time, which tests their ability to compete without injury. The lower limb was observed to be the most impacted body component in both sexes, followed by upper limb and trunk (Starbuck et al., 2016). When compared to women, men had an injury rate that was more than twice as high overall and more than triple that of women (Alexis et al., 2016). The existing literature suggests that when compared to clay courts, hard courts were found to be significantly more foreseeable, having higher grasp, higher hardness, and difficulty to slide on (Starbuck et al., 2016). High loading has been linked to hardcourts, especially on the lateral parts of the foot (Damm et al., 2014). This means that the foot is upside-down. Ankle inversion injuries have previously been linked to high degrees of inversion (Kristianslund, Bahr, & Krosshaug, 2011). The researchers discovered that while there were more incomplete matches for women on Australian hardcourts and more for males on US hardcourts, grass had the fewest of them (Abrams et al., 2012). Lower knee flexion angles are claimed to be produced by cutting tasks on high friction surfaces, which increases the risk of anterior cruciate ligament (ACL) injuries (Dowling et al., 2010). Hard court surfaces, which permit rapid changes in movement direction and high rates of acceleration and deceleration, are likely to put more strain on muscles and tendons. Because of the stress placed on the bone, medial tibial stress syndrome (also known as "shin splints") is frequently mentioned and is more prevalent on hard courts (Damm, 2014).

According to studies, injuries to the back, knee, and ankle joints were the most common, and athletes who played on surfaces that allowed for sliding, like clay courts, experienced considerably less pain and injury than those who played on non-sliding surfaces (Damm. et al., 2013).

The coefficient of translational friction on clay courts is lower than on hard courts. As a result, it has been hypothesized that playing on clay could result in lower frictional resistance and a reduction in joint loadings, which lowers the likelihood of lower extremity injuries (Damm. et al., 2013). The clay court has a longer ground contact time (Starbuck et al., 2016). Results from this study show that playing on clay court surfaces increased the risk of injury for women. In a study of tennis injuries, senior tennis players who had spent their career on clay courts as opposed to hard courts reported fewer knee problems (Abrams et al., 2012). Slow courts, on the other hand, are likely to have a greater incidence of muscular strains/spasms due to the lower frictional coefficient, which results in further sliding motions. Several ligament injuries have been observed on the clay and one could say that the high level of inversion during a sole lateral side-shuffle action might cause a sprain on the ankle. Studies reveal that clay-specific adaptations improve player steadiness. On the clay court, higher hallux pressures and lower midfoot pressures were seen, allowing for sliding while maintaining forefoot grip. However, those with more experience on clay courts may lower their risk of injury due to reduced loading from later peak knee flexion (Starbuck et al., 2015). Significant frictional differences between clay and hard court surfaces. As a result of greater horizontal pressures resisting motion, fixing the foot more firmly to the ground has been linked to an increased risk of both ankle and knee injuries. The main element that could cause sliding is the higher peak horizontal loading rate that was measured on clay and was only seen during the side jump movement (Damm. et al., 2013). Another difference between clay and hard courts is a greater ankle inversion angle during stance (Damm. et al., 2013). Results showed that hard courts required injury care substantially more frequently than clay courts did during matches (Damm. et al., 2013).

On grass, Injuries to the trunks are more prevalent than on clay or hard-court surfaces. Playing on the quicker surface of grass, with a smaller ball bounce and shorter point length, may significantly affect patterns of injury because there is a potential risk of injury when moving from clay to grass. The increased stress felt in the foot on Grass courts can be a possible cause for people playing tennis due to hyper pronation. Moreover, the slipperiness of the court, landing motions or braking actions resulting from side- shuffle movements can result in significant constraint on the musculoskeletal system.

According to research, playing on grass or a hard court increases your risk of needing medical attention compared to playing on clay (Abrams et al., 2012), the risk of injury is the least. Because of the longer braking phase and resulting lower peak force on clay, it may be related to the ability to slide, which has been proposed to be more significant than the cushioning effect of grass for reducing load on the locomotor system of tennis players (Encyclopedia of sports medicine;16).

On the contrary, hard courts have reported higher injury incidences as compared to clay surfaces. Women have reported a higher injury rate on courts of clay, when compared to hard courts (Hartwell et al., 2017). Male athletes, on the other hand, had a higher likelihood to sustain an injury when playing on hard courts than when on the clay ones (Hartwell et al., 2017). The clay courts seemed to have significantly less impact than grass courts or even hard courts. Tennis court surfaces have been identified as a factor which influences the occurrence of injuries. The true impact surface on which tennis is played on injuries is yet unclear. The evidence strongly suggests that the surface is a significant component in injury causation and varying surfaces have been found to have considerably different injury rates.

CONCLUSION

Overuse injuries are highly prevalent in tennis players at competitions of all levels, according to most of the research. Lower limb difficulties have been found to be approximately equal to or exceeding upper limb symptoms among these injuries. The most affected joints were the back, knee, and ankle. It is possible to successfully treat these frequent injuries by understanding how tennis courts affect the pathophysiology of these conditions. Moreover, tennis-specific prevention programs that aim to lower the risk of injuries. The key finding of this research is that there is no discernible difference between the total injury rate on clay, hard, and grass courts. These findings could then be use to encourage further study into tennis injury rates and prevention, as well as to help create training programs. Hard-court players had a greater rate of lower limb overuse injuries, while players who played on numerous court surfaces had the highest injury rates overall. The use of injury prevention techniques should be directed towards these groups. This study may raise awareness of the suitable footwear required for various court surfaces and emphasizes the significance of effective load control to prevent tennis overuse injuries.

The nature of injuries is something that both coaches and top tennis players should be aware of. The specificity principle of training states that workout plans must be tailored to the physical and mechanical demands of tennis. In this way, when coaches decide on specific training plans for high level tennis players, the court surface should be considered as a vital aspect. Additionally, these data should make it possible to provide players with better continuity of care throughout the competitive season. Opportunities to advance the expertise of clinicians working with tennis players and to create efficient, empirically supported injury prevention strategies may then materialize.

CONFLICT OF INTEREST AND FUNDING

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

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Hydration in hot weather: Tennis exercise drink recommendations

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ABSTRACT

It is essential that tennis players have an appropriate, regular, and sufficient fluid intake. Indeed, athletes generally consume much less fluid than the losses induced by thermoregulatory mechanisms (mainly by sweating), caused by the combination of physical exercise and heat-related stress, when playing in hot condition.. This article aims to evoke the physiological and psychological mechanisms involved in the practice of tennis, training, or competition, in hot conditions (i.e., more than 25°C) dry or humid and to propose suggestions concerning the beverage use among tennis players. Applied recommendations, concerning pre- (before), per- (during) and post- (after) exercise hydration, are provided to anticipate and limit performance declines as well as prevent the risk of disorders, physiological conditions such as cramps, premature exhaustion, injuries and even heatstroke, as well as the psychological and motivational damage caused by dehydration.

Key words: drink, tennis, performance, heat.

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INTRODUCTION

Tennis is an intermittent and multifactorial sport that requires a combination of specific physical abilities such as agility, speed, power, muscular and aerobic endurance, as well as mental abilities of anticipation, reaction, and decision-making (Hornery et al., 2007). It is a very popular sport played on all continents and especially in areas of the globe in which ambient temperatures can be hot and exceed 28°C during the day, whether year-round or during summer periods such as summer, such as in countries or areas with a tropical climate (i.e., Brazil, Colombia, Congo, Vietnam, Caribbean), equatorial (i.e., Guyana, Gulf of Guinea, Central Africa, certain islands in the ocean Pacific, Indian Ocean and Southeast Asia), arid (i.e., North Africa, Middle East, Australia, deserts of India, United States) Mediterranean (around the Mediterranean, California, central Chile, Cape region of South Africa), temperate (Western Europe, part of the United States, or South America) or continental (part of North America, Eastern and Central Europe). Indeed, Misailidi et al. (2021) recently reported that 30% of ITF junior tournaments in the last ten years were held in hot, very hot or extremely hot conditions (i.e., 25°C-36°C wet bulb globe temperature: WBGT). Guadeloupe is a good example of a tropical environment, in which the ITF junior tournament in Saint-François takes place, which is in the Caribbean and has a relatively constant average temperature of 26°C with maximums of 34°C and a relative humidity around 80% (Hue et al., 2019). Playing tennis under such conditions involves managing the player's hydration status and drink intake (Fleming et al., 2018) given the combined effects of practice and heat stress that we will, now, approach.

EFFECT OF THE COMBINATION OF EXERCISE AND HEAT

The performance of a sports activity such as tennis generates the production of metabolic heat mainly resulting from the contractions of the muscles which are active during the exercise. In a neutral environment (less than 24° Celsius with a relative humidity of about 30%), this so-called compensable heat will mainly be evacuated by cardiovascular and ventilatory adaptations (i.e., increase in heart rate, respiratory rate, and blood flow towards the skin) and by the evaporation of sweat (i.e., perspiration) at the skin level (Tyler et al., 2016). To a lesser extent, the heat may be evacuated by evaporation from breathing, by convection linked to exchanges between the outside air and the skin (especially when the player is moving) as well as conduction between the latter and clothing fabrics (see figure 1). This will result in a rise in the players' core temperature, which will stabilize at around 38.5°C (Martin et al., 2018).

However, when the humidity in the air and/or the environmental heat increase, the core temperature of the players will also experience an increase which can sometimes go beyond 39.5°C (Bergeron et al., 2007). This increase in core temperature is caused by an exceedance of evapotranspiration capacities, as observed in tropical climates (about 31° Celsius and 75% relative humidity; for a review see Hue, 2011), the evaporation of the sweat is no longer sufficient to evacuate the heat which will be qualified as non-compensable. In addition, in sunny conditions, the body could experience additional heat gain caused by solar radiation (Bergeron et al., 1995), which could be accentuated by wearing dark clothing.

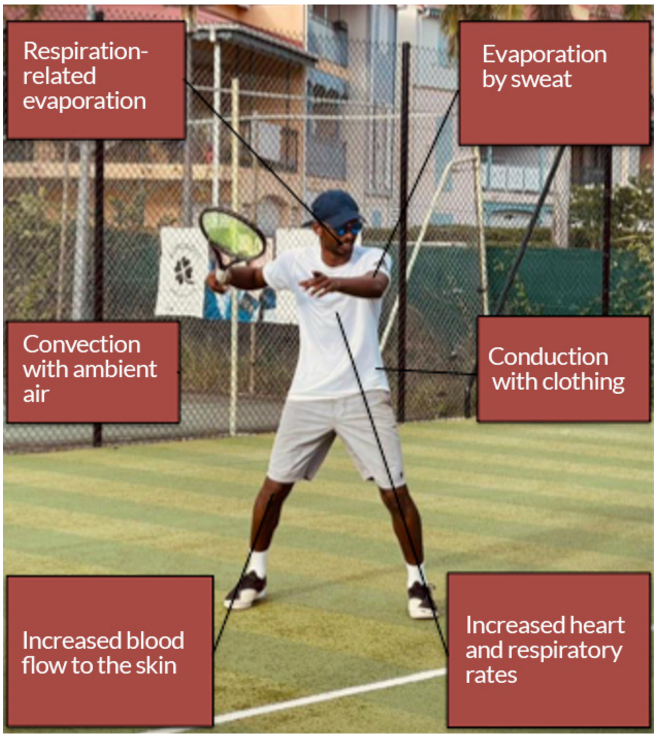

Figure 1. *Mechanisms of heat removal in tennis players*

Physiological dysfunctions (i.e., very high heart rate and core temperature), linked to difficulties in dissipating heat, can reduce sports performance (Hue, 2011; Périard & Bergeron, 2014), promote dehydration in tennis players (Kovacs, 2006) and are also likely to threaten the health of athletes in training or during competitions (Bergeron et al., 2014; Léon & Bouchama, 2015). In addition, it is important to note that playing in hot conditions can also generate psychological and cognitive constraints (i.e., increase in negative effects, limitation of attentional resources) which can promote the early onset of fatigue, amplify perceived effort, increase discomfort, and lower the motivation of athletes (Périard et al., 2014; Robin et al., in press). To limit the deleterious effects of heat, tennis players can use different cooling strategies: internal cooling (i.e., ingestion of cold drinks or crushed ice) and external (i.e., ice packs, cold towel, spray cold water) or acclimatization (Robin et al., 2021) and must ensure that they maintain a good state of hydration and limit dehydration by using appropriate exercise and recovery drinks.

IMPORTANCE OF PRE-EXERCISE HYDRATION STATUS

Body temperature regulation, cardiovascular stress, and heat tolerance during exercise in a humid and/or hot environment are modulated by the hydration status of tennis players (Périard et al., 2021; Robin et al., in press). Hydration, which must be adapted to carrying out intense physical activity and to the environment, is one of the performance factors that should not be overlooked (Guezennec, 2011). It is recommended to drink ad libitum (i.e., to satiety), to be "euhydrated" at the start of practice, and therefore to avoid being dehydrated by being thirsty before playing (Périard et al., 2014). The colour of urine, which should be quite clear, can be used as an indicator of the hydration status of athletes (Teodor, 2017). The "pre-exercise" drink that we recommend players consume is water, especially if they have had a meal sufficiently rich in carbohydrates (e.g., pasta, rice) and protein, at least 3 hours before the start of the practice (Martin, 2018).

It is important to note that tennis players should avoid overhydration, i.e., drinking too much, before playing. Indeed, hyperhydration does not improve thermoregulation or sports performance (Chabert et al., 2019) and can lead to feelings of heaviness, bloating, nausea, or force players to go to the toilet. It will also be suggested to avoid drinks that contain taurine, caffeine, or alcohol because these can accelerate the loss of fluid or to drink too sweet drinks (very rich in carbohydrates) which can cause reactive hyperglycaemia and induce hypoglycaemia at the start of practice. The recommendations will be to ingest around 6 ml of drink per kg of body mass (Martin, 2018) around 2 hours before the practice (see table 1).

Table 1

Recommendation concerning the ingestion of drink, before the effort, according to the body weight of the players, centilitre (cL).

Body mass	40kg	50kg	60kg	70kg	80kg	90kg	100kg	110kg
Beverage volume	24 cL	30 cL	36 cL	42 cL	48 cL	54 cL	60 cL	66 cL

NEED TO STAY WELL HYDRATED DURING EXERCISE

When playing tennis in a hot environment, the increase in perspiration caused by the physiological mechanisms of thermoregulation can induce bodily dehydration which will increase with the waning of physical practice (Baker, 2007), if it is not compensated by fluid ingestion. For example, it has been shown that tennis players can lose up to more than 3 litres of body fluid per hour of tennis practice, especially in hot conditions (Guezennec, 2011; Martin, 2018). However, the feeling of thirst is not a good indicator of hydration status, players are at risk of drinking too little and will not be able to compensate for body fluid losses caused by exercise and heat. Indeed, even if athletes ingest drinks as soon as they feel the urge to drink (during breaks or changing sides in competition), dehydration can still occur and will worsen as the training or match times increase (Garth & Burke, 2013). However, excessive dehydration (beyond 2% loss of body weight) can cause, in addition to reduced performance, cramps, discomfort, exercise hyperthermia (i.e., heat stroke) or even worse cause death (Bergeron, 2013). Therefore, we urge athletes to exercise the utmost caution and advise them to test and integrate fluid management (i.e., composition, volume, frequency of drink ingestion) into their training and performance routines, to compensate for losses of fluids, electrolytes such as sodium or carbohydrates.

For efforts lasting approximately one hour, several authors indicate that water may be sufficient (i.e., Bergeron, 2022; Teodor, 2017). However, the decrease in sodium in the blood plasma, caused by sweating, is an important factor in fatigue and reduced performance (Vrijens et al., 1999), which is why it is necessary to provide a moderate intake of sodium (between 500 mg and 1 g per litre, which corresponds approximately to 1 to 2 pinches of cooking salt) in the drink for efforts of more than one hour. Similarly, carbohydrate supplementation (about 20 g per litre, which corresponds to 4 teaspoons or 4 sugar cubes) will be recommended to meet the body's needs when playing in hot conditions (see Guezennec, 2011 for specific recommendations depending on the outside temperature). In addition, the use of flavoured drinks may increase the volume of drinks spontaneously ingested. Finally, it is important to remember that substances such as vitamins, caffeine, arginine, or taurine are not part of the European recommendations concerning the composition of exercise drinks in sport.

During tennis practices of more than 1 hour, carried out in hot conditions, it is recommended to have exercise drinks containing carbohydrates and electrolytes (mainly sodium), which make it possible to increase the ingestion of liquid, delay the onset of fatigue and slow down the increase in core temperature, thus limiting the impact of heat stress (Bergeron et al., 2006). Players have the option of composing their drinks themselves (see figure 2).

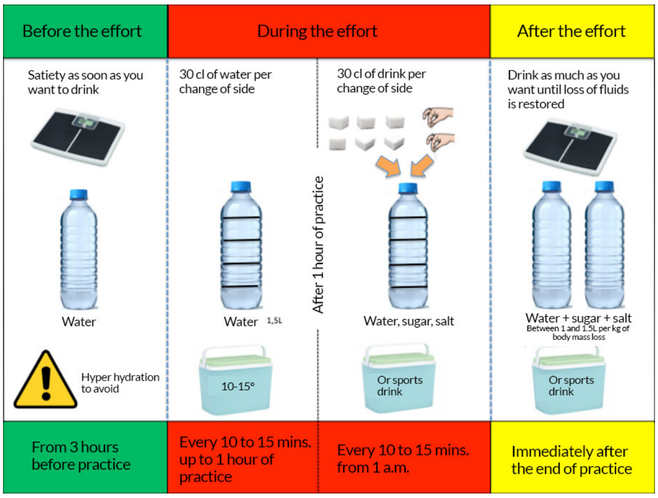

Figure 2. *Drink preparation options.*

It is generally suggested to ingest at least 30 cl of drink (Martin, 2018) during side changes, which generally take place every 10-15 minutes in matches. However, these suggestions can be adapted and personalized according to the sweating rate specific to each player (which can range from less than 1 litre per hour for those with "low" sweating to more than 3 litres per hour for athletes with a profuse sweating) and their gastric emptying (between 1 litre and 1.6 litres per hour). To allow players to drink the sufficient and recommended amount of liquid, we suggest making marks on the 1.5-liter bottle for example (see figure 2).

In addition, the temperature of the ingested liquids must be considered. Indeed, although frozen drinks could be used as an "internal cooling strategy" as reported in the literature (i.e., Douzi et al., 2020), these can have undesirable effects such as causing discomfort when ingestion, cause headaches (i.e., cold-related migraine) or even have a braking effect on thermoregulation processes by acting on deep thermal receptors (Guézennec, 2011). Therefore, we recommend the use of cold drinks at temperatures between 10°C and 15°C, stored in coolers or thermos flasks, which while promoting central cooling will be more easily consumed by players.

DO NOT NEGLECT POST-EXERCISE REHYDRATION

Immediately after exercise, the priority is to replace lost fluids, electrolytes, and carbohydrates (Bergeron et al., 1995). This can be done with water and a balanced meal rich in proteins, carbohydrates and salt which will replace the loss of sodium caused by sweating, stimulate the absorption of glucose, and promote the retention of absorbed fluids. According to Guezennec (2011), the optimum volume of drink is 1.5 litres for each kilogram of body weight lost during exercise.

However, when players must play very close matches one after the other, it is advisable that rehydration be done with a drink containing carbohydrates and electrolytes including sodium but also potassium (Kovacs, 2008). We also recommend favouring cold and flavoured drinks (i.e., using syrups of different flavours) according to the tastes of each athlete to promote ad libitum liquid absorption after exercise. A small quantity of solid and easily digestible food can be consumed at the same time as the ingestion of drinks.

If sweat losses in the previous match are excessive (significant difference between player's pre- and post-match weight), or if athletes have heat-related muscle cramps, it may be appropriate to add a little more salt to the drinks and food ingested to start the next match by being "euhydrated" and to prevent or limit the appearance of cramps. Regarding carbohydrate intake (i.e., carbohydrates) it will be recommended to consume 1.5 g per kg of body mass, which represents 60 g when you weigh 40 kg, 90 g for 60 kg, 120 g for 80 kg and 150 g per 100 kg of body mass to be ingested in solid and/or liquid form in the first hour after exercise (Kovacs, 2006).

CONCLUSION

Before starting training or a tennis match in humid and/or hot conditions, we recommend that players drink regularly as soon as they feel like it, and above all not to start playing while being dehydrated. During practice, it is suggested to regularly drink about 30 centilitres (cL) of water every 10-15 minutes for the first hour and then to use a drink containing carbohydrates and sodium when the effort lasts longer. This drink can be easily made or purchased commercially. Finally, it will be important for the player to rehydrate after exercise, to restore losses of body fluids and electrolytes. This rehydration must be done by means of drinks containing carbohydrates, sodium, and potassium and which can be supplemented with a balanced meal or a snack containing proteins.

CONFLICT OF INTEREST AND FUNDING

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Feedback and learning in tennis: Conceptualisation, classification, and practical implications

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ABSTRACT

This article defines the concept of feedback, proposes a classification of the different types of feedback, and explores the application of extrinsic feedback by tennis coaches. Furthermore, the influence of feedback on the learning and performance of tennis players is analysed. Finally, a series of practical implications that coaches can consider evaluating the feedback they provide to their players and to make the teaching-learning-evaluation process more effective in their training sessions are presented.

Key words: knowledge of results, knowledge of performance, communication, teaching.

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INTRODUCTION

When a new player takes up tennis and wants to learn the basics, or when an experienced player wants to improve their performance, it takes time for an improvement to occur. One possible way to facilitate improvement may be to try different strategies gradually through trial-and-error learning. Another way may be to get feedback from external sources, such as a coach or video footage (Lauber and Keller, 2014).

According to Ruiz Pérez (2001), the concept of feedback was first formulated by Nyquist in 1932 and is defined according to Sage (1977), in Oña (1999) as "the information that an individual receives as a result of a response". From the point of view of motor learning, Pieron (1999) defined feedback as the "information provided to the learner in order to help him/her to repeat the appropriate motor behaviours, eliminate the incorrect ones and achieve the desired results".

According to these definitions, feedback is associated with the information provided by the teacher, peers, or audio-visual systems. However, we must think of the learner and his or her ability to learn by himself or herself. Therefore, feedback can be classified into two subcategories: firstly, internal, intrinsic, inherent, and sensory feedback, which would be, according to Batalla (2000) "the information that an individual obtains about his or her own execution of an action". This is fundamental for movement control and involves a complex cognitive process. Secondly, we find the supplementary or augmented feedback that refers to additional information (quantitative or qualitative) from an external source.

Depending on the situation, supplementary feedback can be provided in two different ways: as knowledge of results or as knowledge of performance. In the first case, the information provided refers to the achievement or non-achievement of

the external target, while in the second case, the information provided refers to the execution of the movement pattern (Oña, 1999).

In addition, another concept that we cannot overlook is that of feedforward, understood by Cano et al. (2017) as "the sensory representation of the action or movement that the learner intends to perform and that is sent in advance to prepare a part of the system to receive the feedback".

In summary, we can define feedback as "the set of internal and external information aimed at improvement in order to readjust and stabilise motor responses".

Although, as we have just seen, feedback can be classified into two types, depending on who provides the information:

intrinsic and extrinsic or augmented, in this article we will focus on the second type, since, as coaches, it will be the one that is particularly relevant in our tennis lessons. Therefore, the objectives of this article will be 1) to classify the different types of feedback and their characteristics, 2) to analyse the influence of feedback on the learning and performance of tennis players and 3) to expose practical implications for tennis lessons, based on the information exposed.

TYPES AND CHARACTERISTICS OF FEEDBACK

To establish as broad and precise a classification as possible, a synthesis of various proposals has been made (Pérez, 2001; Oña, 1999; Gutiérrez, 2008; Cano et al. 2017; Haibach et al. 2011). Thus, Table 1 presents a classification of the different types of feedback.

Table 1

Types and characteristics of feedback.

Ranking	Type	Definition	Example
Depending on the moment	Concurrent or simultaneous	Information is provided during the action	"Take back the racket now".
	Terminal or immediate	Information is provided at the end of the action	"On this forehand, you should have taken the racket back earlier".
	Postponed or delayed	When a time interval is allowed to elapse between the action and the provision of information	"On the forehands you hit yesterday, you should have taken back your racket earlier."
Depending on the manner of reporting	Non-verbal	The way of transmission is not oral	The coach demonstrates a slice backhand.
	Verbal	The way of transmission is oral	The coach explains the execution of a slice backhand
According to the degree of specificity of what is being reported	Analytical	Refers to specific aspects of the action	"Note the position of the wrist when hitting".
	Global	A generic estimate of the action is made	"That stroke is very fluid."
Depending on the target audience	Individual	Single player	"Pepe, move faster!".
	Group	To a group of players	"Guys, move faster!".
According to frequency	Separated	Refers only to the last action	"I really liked this last shot".
	Accumulated	It refers to an accumulation of actions	"I really liked the last series of shots".
Depending on the intention	Descriptive	Provides exteroceptive information on how the action has been performed	"You've hit the ball between the shoulders and the hips".
	Evaluative	Assesses the student's performance	"You've hit it very well."
	Comparative	It draws an analogy between one action and another.	"This shot was better than the last one".
	Explanatory	It constitutes a cause-effect correlation.	"When you hit the ball at that height you have more control".
	Prescriptive	Affirms how to perform the action correctly	"Try to hit between the shoulders and the hips".
	Affective	Motivates the student to continue practising	"You're improving a lot, thanks to your attitude".
	Interrogative	The player is asked about the action	"How high do you think you hit the ball?"

INFLUENCE OF FEEDBACK ON LEARNING AND PERFORMANCE OF TENNIS PLAYERS.

Feedback serves as a hinge between teaching and learning, being an important variable for learning to take place. Some classical authors claim that feedback is essential and that it is the main characteristic of efficient teaching (Mosston & Assworth, 2008). Furthermore, some studies have concluded that simple repetition does not ensure motor learning and that the suppression of feedback can lead to a degradation of performance (Simonet, 1986). For Haibach et al. (2017) feedback is the most important route to motor learning, except of course, practice itself.

Regarding the objectives pursued when using feedback, Ruiz Pérez (2001) states that the three main objectives are:

- Inform the learner about what he/she is doing and how he/she is doing it.
- To motivate the learner by providing sufficient encouragement to keep practising until the precise objective is achieved.
- Reinforce or strengthen the response that the subject makes, which means getting closer to the desired value.

In addition to these 3 main effects, according to this author, others can be added such as correcting errors, favouring self-observation, saving time and effort, orienting attention towards what is relevant and developing strategies.

Other authors qualify these objectives by stating that the main objective is to improve response through error correction and that the rest of the objectives, such as motivation, strategy development, etc., are collateral objectives (Oña, 1999).

In the specific case of learning in tennis players, there are several studies that have analysed the relationship between the feedback provided to players and their learning or performance. Most studies have focused on the acquisition of skills, evaluating how different types of feedback affect the improvement of strokes.

Regarding the serve, some research has found that providing immediate increased feedback on speed (e.g., by indicating the values obtained through a radar) can support the learning process to serve faster in elite players (Moran et al., 2012; Keller et al., 2021). Furthermore, it was also indicated that increased service speed was not associated with lower accuracy (Keller et al., 2021).

The effect of increased feedback has also been observed in the forehand stroke with beginning players. In this case, players who received analytical feedback from the coach showed improvements in accuracy and execution after the training process. However, another group of players who only performed self-talk, without coach intervention, improved in the same way (Cutton and Landin, 2007).

Augmented feedback has also been shown to be positive in volley learning. Hebert and Landin (1994) found that players who received augmented feedback from the coach improved both accuracy and execution of volleys.

PRACTICAL IMPLICATIONS FOR TENNIS LESSONS.

Following the classification proposed above and based on the information presented in this article and other studies, we are going to present the main aspects that tennis coaches should consider regarding the feedback given to players in their tennis lessons.

Depending on the moment

It is recommended that feedback is provided between 10 and 25 seconds after the execution because, if it is given concurrently, it would interfere with the rest of the stimuli that the players must attend to, and if it is given immediately, it would interfere with the intrinsic feedback. Therefore, it is preferable to leave sometime between the execution of the action and the provision of feedback by the coach so that the players can evaluate the action themselves (Ruiz Pérez, 1994; Reid et al., 2006; Haibach et al., 2017; Cano et al., 2017).

Depending on the way of delivery

Regarding the use of verbal and non-verbal feedback, both types of feedback are complementary, and coaches should be aware of the different situations and personalities of players to confirm which type of feedback is more effective. In general, it is recommended that both types of feedback are combined, and that verbal feedback is not abused. In this regard, Reid et al. (2006), indicate that too much feedback leads to increased dependence on the coach and limits the player's ability to process and evaluate information independently.

According to the degree of specificity of what is being reported

Generally, it has been observed that feedback is most useful when it is simpler, refers to a single characteristic of the skill and focuses on the most relevant aspects of the action. However, it is important to consider the type of action and the level of the players. In the early stages of beginning players, more global feedback and the use of analogies can be provided, however, as the level of the player increases and the actions become more complex, it is recommended that feedback is more precise or analytical.

Depending on the target audience

If we refer to feedback related to learning skills, it is recommended that feedback is individual and refers to the specific characteristics of the action and of each player. Group feedback can be useful in the initial stages of learning, with groups of players with the same level of competence. In these cases, for example, the main characteristics of a stroke or action can be explained together.

According to frequency

It seems most appropriate to provide cumulative feedback every 3 or 4 trials. In this way, the player can develop strategies for orienting attention and interpreting his or her results. However, it is important to consider the learning stage of the players and the complexity of the tasks. In this regard Wulf et al. (1998) indicate that with beginning players or during the learning of complex actions, coaches may have to provide feedback more frequently. However, as players increase their level of competence, feedback should be less frequent and intrinsic feedback should be prioritised (Reid et al., 2006).

Depending on the intention

Although in our work as tennis coaches, all types of feedback can be useful depending on the situation, the ones that will be particularly relevant for our students' learning will be explanatory and prescriptive feedback. Again, it will be important to consider the level of competence of the players. As players become more proficient and more autonomous, interrogative feedback can be a good resource to enable players to self-evaluate and propose their own motor solutions. In addition, this type of feedback can also be very useful in the early stages to encourage discovery learning.

CONCLUSIONS

The feedback provided by the coach is a transcendental variable in the teaching-learning process that takes place in tennis lessons. Therefore, it is important for coaches to reflect on the feedback they provide to players. In this article we have proposed a classification and some implications that coaches can consider improving their communication with players and make the teaching-learning-evaluation process more effective.

CONFLICT OF INTEREST AND FINANCING

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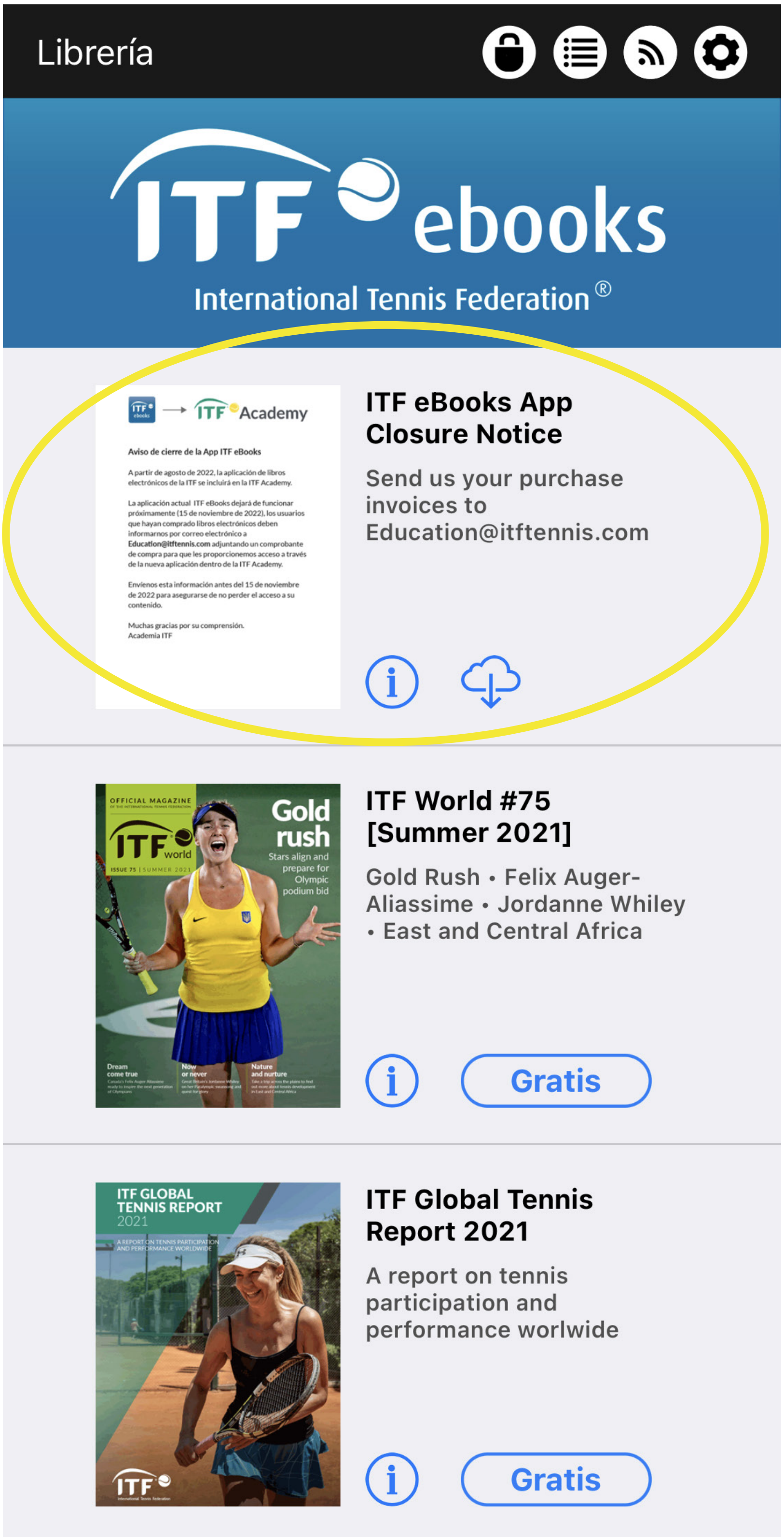

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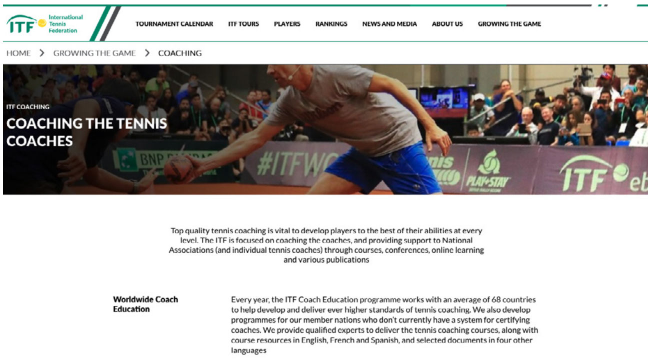

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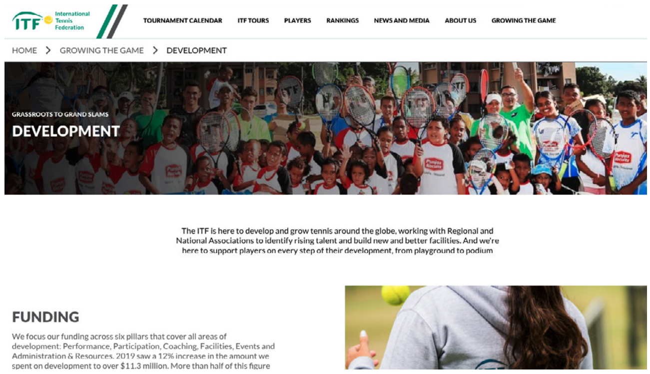

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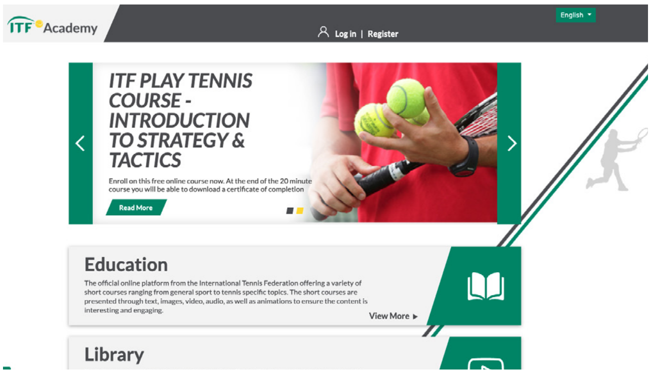
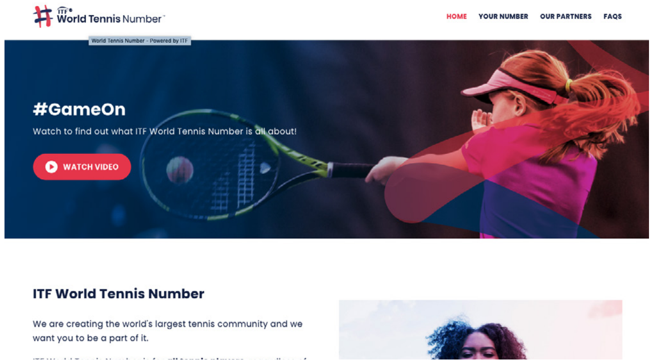


WTN:



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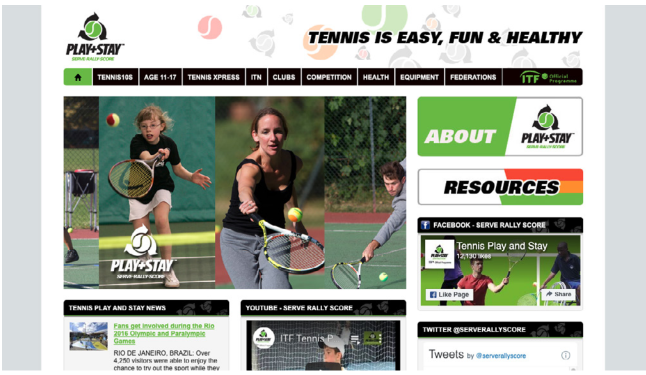

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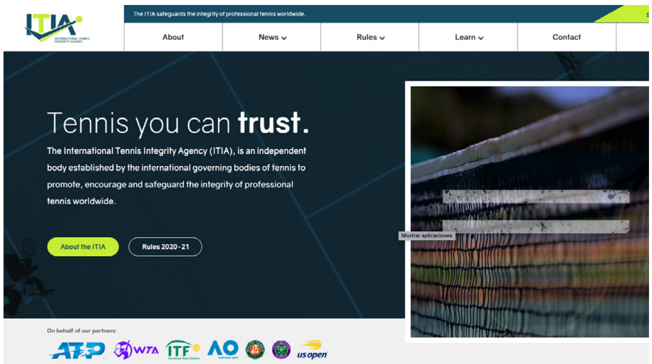

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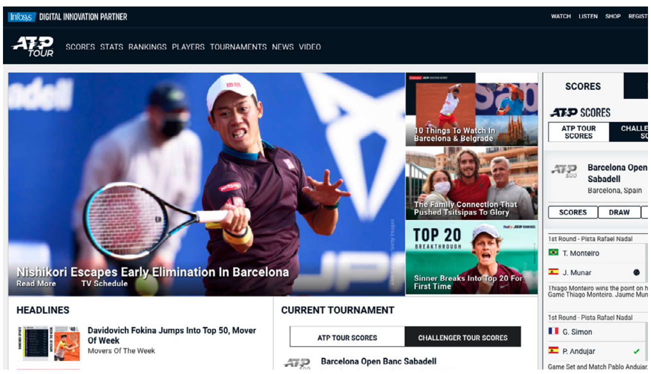

WTA: