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# Determining the tactical and technical level of competitive tennis players using a competency model: a systematic review

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**Introduction:** The aim of this systematic review is to provide an evidence-based synthesis of the literature on the topic of technical and tactical competencies of tennis players and to answer the following research questions: (1) What is the state of the art of research on technical and tactical competencies (i.e., skills and knowledge) and tennis; (2) What are the most important topics related to technical and tactical competencies in tennis players.

**Methods:** Electronic searches were conducted in Web of Science, PubMed and SPORTDiscus (August to September 2023). This systematic review was conducted in accordance with PRISMA guidelines. To reduce risk, all published literature was searched and primary studies were included. The search terms included skills or competencies, match or play, player and tennis and excluded studies on non-competitive tennis players—notation analysis, AI method, systematic review and validation of tools.

**Results and discussion:** Of the 390 publications found in these searches, 13 articles were considered relevant and included in this study. They were divided into three categories: (1) technical-tactical skills, (2) match situations and (3) match performance. There was clear evidence that there is a test instrument for analyzing tactical-technical skills that has sufficient reliability and validity and is of practical value to tennis coaches. The development of tactical-technical skills is influenced by method (variability between/within skills), conditions (court size, ball type) and areas of development (situational awareness, anticipation, decision making). There are differences in match and stroke performance between different quality groups (professionals, juniors), which can also be influenced by mental strength. For a comprehensive study of tennis players' abilities, the use of modern technologies is possible and necessary in the future. Future research should focus on the creation of competency models for the playing level of tennis players, which could include at least three key elements: (1) key competencies, (2) description of standards, (3) evidence.

## KEYWORDS

tennis, skills, knowledge, game situations, match performance, analysis

## Introduction

Tennis is a complex, dynamic and open sport where players strive to achieve a certain level of play by effectively implementing the different components of the game such as the strategy, condition, mentality, and technique to increase the probability of improving their performance and eventually winning more matches (1, 2).

In this context, the players' level of play and their success in tennis, as in many other aspects of life and sport have a considerable importance and they are very closely interrelated. The level of play of a given tennis player can be understood as a multifaceted construct, encompassing a range of physical, mental, and technical skills. It also includes factors related to the strategical and tactical knowledge of the player, as well as external factors such as equipment and coaching (3). For instance, from a psychological perspective research has shown that tennis players believe that ability, maintaining a positive attitude, being task oriented, and focusing on effort were the primary causes of the improvement of their level of play and thus their success (4). As indicated by Elliott (5) *"Success in tennis requires a mix of player talent, good coaching, appropriate equipment, and an understanding of those aspects of sport science pertinent to the game"* (p. 392). From a biomechanics perspective, this author considers that *"Success in tennis is greatly affected by the technique a player uses and biomechanics plays an integral role in stroke production"* (p. 392).

As per the tactical components of the game, the level of the players and their success has also been a relevant topic of research. Authors have investigated level of play and success factors in the tactical space for junior tennis players (6). In this context, the purpose and nature of adequate competition has been defined, discussed and analysed as a fundamental aspect to ensure the proper pathway to improve the level of play and facilitate success from 10-and-under tennis onwards (7). From a conditioning and movement perspective, the nuances of positioning, displacement, recovery according to the physical and physiological demands of the game have also attracted the interest of researchers (8).

When adopting a developmental approach on the factors that affect the players' level and success in tennis, researchers have also explored the importance of performances in youth and junior competition as an indicator of later success in tennis (9). Furthermore, this topic, the level of play and the success in tennis has not only been explored individually from the players perspective but, also, when considering a wider view as a performance indicator for nations when researchers have analysed the factors which explain nations' success in tennis (10). In this context, the tournament structure and geography of tennis events and how these affect the level of play and the subsequent success of players has also been a subject of investigation (11).

From a long-term player pathway approach, at the grassroots level of play, tennis success has been considered on a developmental perspective (12). The level of play and success of young players stepping onto the court for the first time may be considered in terms of skill acquisition, enjoyment, and the

development of a passion for the sport (13). According to the various tennis-specific player development models (14, 15), early success is linked to the attainment of a certain level of play defined by the acquisition of fundamental movement skills and the cultivation of a positive attitude towards physical activity. This foundational achievement of a given level of play and the subsequent success set the stage for a lifelong engagement with tennis, irrespective of future competitive pursuits (16).

In addition to tactical and technical skills, a tennis player's level of play (17) and success has been shown to be influenced by many internal factors, such as the level of psychological (18) and conditioning preparation (19), level of experiences, daily performance, and external factors, which primarily include the opponent (20), playing surface (21), tournament round, weather conditions (22), referee decisions, and spectators (23).

Competency and competency model are common terms that have received considerable attention from researchers in different fields. The competency model is a framework widely used in the accreditation of professions as organisations have shown interest in the development of competencies for different occupations (24). For instance, in the sports science and medicine context different organisations have created a group of prescribed competencies or indicators related to how the professions of these sports professionals are defined and assessed. The competency model is increasingly being used in sport to determine success and efficiency (25). Specifically in the case of the sport domain, Siedentop, Hastie and van der Mars (26) defined a competent athlete as someone who has developed sufficient skills to participate satisfactorily in games and activities, who understands and can execute strategies appropriate to the complexity of the activity, and who is a knowledgeable athlete with specific cognitive, psychomotor, tactical and technical skills. In racket sports, competence is defined as the knowledge, skills, behaviours, attitudes and abilities to do something successfully or efficiently, including technical skills (e.g., shot accuracy), tactical awareness (e.g., decision making), physical fitness (e.g., agility) and mental aspects (e.g., concentration) (27). Specifically, skills in tennis have been understood as specific actions (e.g., shots and movement patterns) that can be developed through training and practice (28).

The use of competencies and competency models for the identification and categorisation of tennis players has been a usual policy by many tennis organisations as part of their player development strategy. For instance, as an example, in the case of the United States Tennis Association (USTA), the American Development Model (ADM) is a competency-based framework aimed at providing guidelines to work with players at the different levels of the game (29). Furthermore, the International Tennis Federation (ITF) as well as a considerable number of national associations are also using a competency-based structure in their coach education programmes to facilitate the coaches' pathway (30). Being able to define and allocate the appropriate player competencies to the different levels of the game is of paramount importance to enhance the quality of both coaching and coach education programmes (31).

Research on specific competencies in the tennis domain is somehow fragmented and unclear as it covers a multiplicity of

subtopics and approaches that may generate confusion in this relevant issue. Some studies have explored the professional competencies of tennis coaches (32, 33). As per the players, evidence in tennis has focused on the measurable and observable results that demonstrate a player's competencies. These competencies have been understood as the combination of their knowledge and skills as related to the game in general and to match play in particular. It involves performance indicators (e.g., percentage of strokes or points and success, position, speed and placement, position and movement of the player,...) and other data (temporal characteristics, heart rate, heart rate variability,...) that provide objective information about a player's efficiency and effectiveness (34).

Evidence can be collected through various methods. In the past, researchers analysed tennis play using time-consuming video analysis. Today, various tools are available for in-depth analysis of tennis play, including technologies that automatically track the ball and the tennis player (Hawk Eye, FoxTen) or wearable devices that are attached to the tennis racket or the player (35). Researchers have analysed different areas of the game and gathered increasingly detailed information, such as the relationship between the players' competitive level and their ranking (36), the playing characteristics on different surfaces (37), a better understanding of the differences between players of different levels of play (6, 38, 39), and between winning and losing players (40, 41), or between players of both genders (38, 42).

Some of the studies have focused on the search for specific performance indicators that influence tennis performance (43, 44), methods to determine stroke type and external load (Whiteside et al.), hitting load and running distance, and movement velocity (45). Research has also analysed serve position, velocity, projection angle, landing position, and relative position of the player when executing a serve (46), as well as movement characteristics, groundstroke velocity, and net clearance of strokes (44).

In terms of studies related to level of play, tennis, a sport known for its elegance and competitive spirit, unfolds on a vast spectrum of levels, ranging from grassroots participation to the pinnacle of professional tournaments (47). Researchers have tried to delve into the diverse competences needed to achieve success at various levels of tennis play, acknowledging the subjective nature of accomplishment, the evolving criteria that define it, and aiming at exploring objective features that would allow to better determine the various levels of the game (48).

Moving up the ladder to junior and amateur levels, success begins to intertwine with competitive achievement. Here, players may gauge success by their ability to navigate local and regional tournaments, climb the rankings, and secure scholarships to advance their education while pursuing their tennis aspirations (49). As an example, the work of Gould et al. (50) among others, sheds light on the importance of appropriate player-parent relationships and the role of positive coaching in shaping success at these levels. Success is not only about winning matches but also about overcoming challenges, refining skills, and establishing a competitive identity.

Authors such as Pummell & Lavallee (51) have explored the path of players in the junior-to-senior transition as moving into the professional realm, success undergoes a paradigm shift, with a

heightened emphasis on rankings, Grand Slam victories, and financial gains. Scholars such as Li et al. (52) emphasize the significance of mental resilience, adaptability, and strategic career planning in achieving success at the professional level. Success in professional tennis is intricately linked to a player's ability to navigate the complex interplay of physical fitness, mental toughness, and strategic decision-making in an intensely competitive global landscape.

An interesting area of research has been the determination of the different levels of what can be considered quality in tennis. In most cases, the individual level of tennis players has been determined using rankings (53–55), player experience (56), and analysis of selected performance indicators (57, 58).

From a content perspective, it seems obvious that there is a considerable body of research on aspects related to the technical (biomechanical) and tactical (strategical) components of the game. The studies focused on stroke production (technique) and match performance (tactics) have received a considerable attention from researchers when investigating the main performance indicators that determine the various levels of play.

Despite the importance of the definition and the categorisation of the specific competencies that players need to master at the different levels of play, it can be observed that the state of research provides a fragmented view on this topic with a considerable relevance of studies on skills and performance indicators but a lack of research and application on competency-based analysis and understanding of the various levels of play that define a player.

Thus, the aim of this systematic review is to provide an evidence-based synthesis of the literature on the topic of technical and tactical competencies of tennis players and answer the following research questions: (1) Which is the state of research on technical and tactical competencies (i.e., skills and knowledge) in tennis; (2) Which are the main themes related to technical and tactical competencies as applied to tennis players.

## Methods

### Search strategy

This systematic review was conducted in accordance with PRISMA guidelines (59). An extensive search of the research literature was conducted to systematically review the competencies of tennis players. The search spanned from August to September 2023 and included literature from online databases such as Web of Science, PubMed, and SportDiscus. The search terms used in the electronic database were ("skills" or "competencies") and ("match" or "play") and "player" and "tennis" (Table 1). In addition, the reference lists of included articles were manually reviewed to identify additional relevant studies for review.

### Inclusion and exclusion criteria

In accordance with the PICOS (Population, Intervention, Comparison, Outcomes, and Study Design) method (60), the following inclusion criteria were used to select articles for this

TABLE 1 Databases, search items and inclusion/exclusion criteria overview.

| Databases                             | Search terms   | PICOS        | Inclusion criteria  | Exclusion criteria  |
|---------------------------------------|--|--------------|---|---|
| Web of science Pub<br>Med SportDiscus | Tennis, competencies, skills,<br>match, game, player | Population   | Male and female tennis players at junior, national, or international match level                                  | Recreational tennis players   |
|                                       |  | Intervention | Analysis, validation and evaluation of tactical and technical performance indicators Time-motion characteristics  | Physiological and physical demands<br>Psychological and mental predictors |
|                                       |  | Comparison   | Between tactical-technical performance indicators and effectiveness   | Only between one aspect of the game and the success of the players        |
|                                       |  | Outcome      | Useful tool to monitor technical and tactical content; identify differences between junior and professional games | Outcome does not allow generalization at the skill level                  |
|                                       |  | Study design | Comprehensive study with multivariate variables   |   |

review (Table 1). (1) Inclusion criteria: Male and female tennis players at junior, national or international competition level, (2) Intervention: analysis, validation and evaluation of tactical and technical performance indicators and time characteristics. (3) Comparison: between tactical-technical performance indicators and effectiveness. (4) Results: Useful tool for monitoring technical and tactical content; identification of differences between junior and professional games. (5) Study design: Comprehensive study with multivariate variables.

Studies were excluded according to the following criteria: (1) Non-competitive tennis players (understood as recreational players); (2) Physiological and physical demands and psychological and mental predictors; (3) Only between one aspect of the game and the success of the players; (4) Outcome does not allow generalization at the skill level; (5) Studies written in languages other than English and Spanish. A reviewer checked every data set and every document found. The steps applied in the systematic search led to the identification of 13 relevant articles for further analysis, the data of which were obtained or confirmed by the reviewers (Figure 1).

The quality of the applied methodology in the included articles was assessed using the Critical Review Form—Qualitative Studies (61). This tool can be used to evaluate many types of qualitative studies. This method was applied to assess each article according to the following categories: study purpose, literature background, study design, sample, outcomes, data analysis methods, results, conclusions and implications for future research. These questions were assigned a score of either 1 (meet the criteria) or 0 (do not meet the criteria). The seventh and eighth questions were exceptional, as a NR (not registered) score could also be assigned to articles.

An NR score means that no information was available on the reliability or validity of the instruments used in this systematic review. For the fifth question, articles that reported on studies with a sample size of at least 21 were assigned a score of 1, as this was the number required to achieve a statistical power of 0.80 or more to detect a large (one-sided) difference at a 5% significance level. The scores obtained for the 14 questions were totaled for each item, with the NR score counted as 0. Two experts independently assessed the quality of the selected items. Table 2 shows the methodological quality of the studies examined.

## Results

In order to facilitate the presentation of the results, this section presents the findings of our study by organizing them according to the two research questions mentioned in the introduction, which refer to the state of research on technical and tactical competencies (i.e., skills and knowledge) in tennis and to the main issues related to technical and tactical competencies in relation to tennis players.

(a) State of research on technical and tactical competencies (i.e., skills and knowledge) in tennis

Table 3 shows the authors of the studies, the number, gender, age, performance level, and tennis experience of the subjects, the research area, and the results reported in the 13 articles included in the review.

(b) Main themes focused on technical and tactical competencies as applied to tennis players.

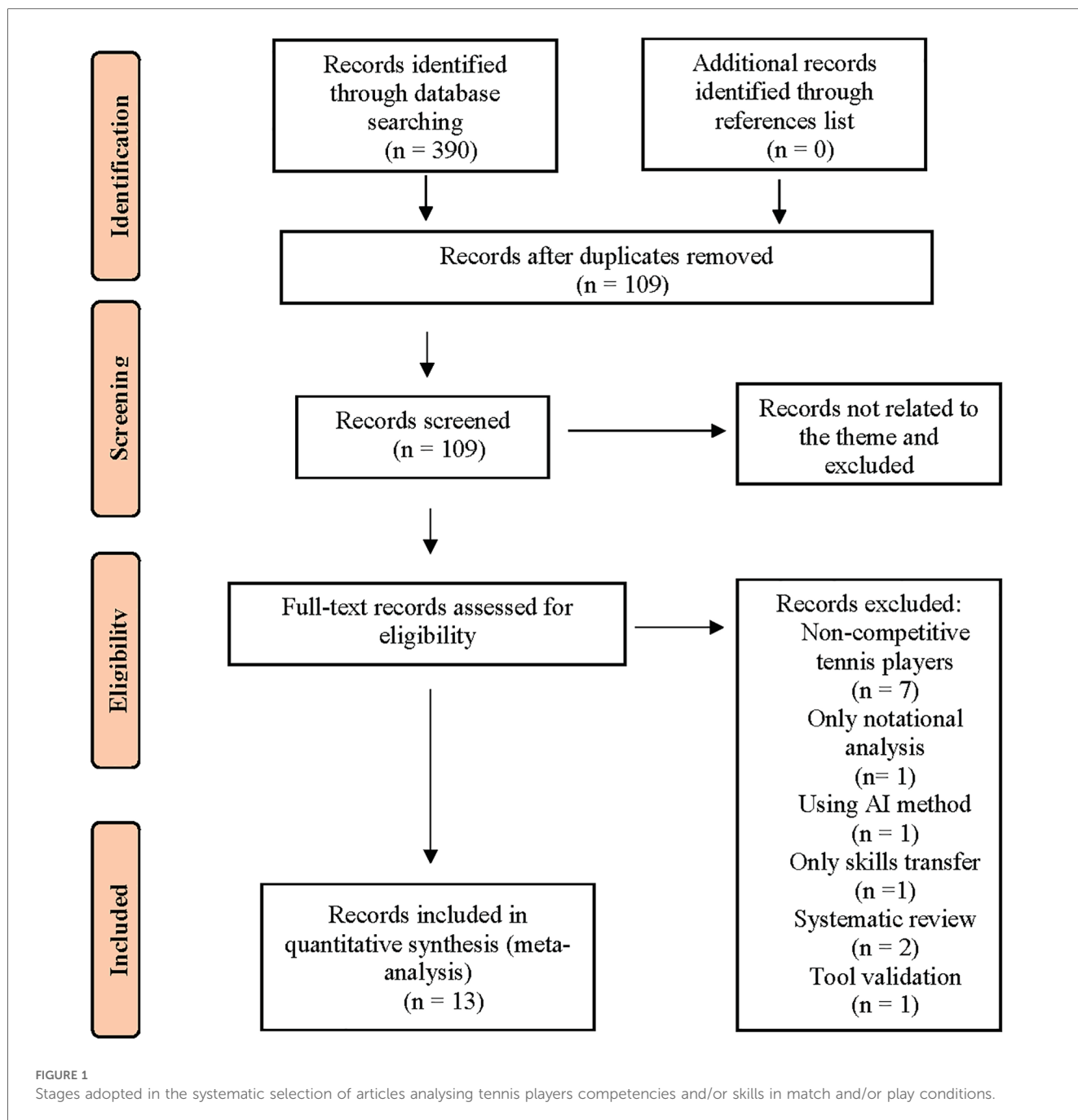
In the articles selected, the main topics studied included the following: technical-tactical skills, game situations, and match performance. The results will be presented according to the different studies grouped according to these main topics.

### Technical-tactical skills

Eight studies analysed tactical-technical skills (62, 63, 66, 68–70, 72, 74). Five of these studies were of high methodological quality, and three studies were of good methodological quality.

The contextual interference (CI) effect is a well-established phenomenon in motor learning and was discussed in an article of Buszard et al. (62) that was split into two studies. In the first study, video clips were used to observe the type of tennis stroke, the side of the serve and the placement of the serve. They differentiated between-skill and within-skill variability during practice. No differences in between-skill variability were observed in young tennis players during serve training. Within-skill variability was greater for the placement of the serve than for the side from which the young tennis players served. No significant correlations were found between serve accuracy and between-skill or within-skill variability.

In the second study, the effect of CI on serve learning was examined under “blocked” (low CI) and “serial” (moderate CI)



practice conditions. The percentage of serves that reached the target was higher in moderate CI than in low CI, there were no differences in the percentage of successful serves and in serve velocity, while serve displacement was lower in the low CI group and serves were directed towards T (skill test) in the post-test.

The effectiveness of tennis training instructions on situational awareness (SA), anticipation (A) and decision-making (DM) was investigated by Caserta and Singer (63). After receiving instructions, participants responded to a series of edited video clips. The results suggested that combined SA, A, and DM awareness training is effective in improving performance. They concluded that no difference was found between implicit and explicit learning strategies.

In another study, the importance of decision-making for the performance of tennis players was explored by García-González et al. (70). The decision training programme was based on an analysis that combined tactical questions and video feedback on the players' own actions. The experimental group significantly improved decision making and performance and maintained these improvements during the retention phase. The authors concluded that video feedback in combination with questions can be recommended to improve tactical decision making in tennis.

Dimic et al. (66) analysed the less discussed area of anticipation, more specifically the influence of stroke intentions and "disguise" on a player's performance in a match. Disguised strokes resulted in a significantly higher proportion of incorrect

TABLE 2 Methodological quality of reviewed articles.

|                             | Question number |   |   |   |   |    |    |    |   |    |    |    |    |    | Total |
|-----------------------------|-----------------|---|---|---|---|----|----|----|---|----|----|----|----|----|-------|
|                             | 1               | 2 | 3 | 4 | 5 | 6  | 7  | 8  | 9 | 10 | 11 | 12 | 13 | 14 |       |
| <b>Author (year)</b>        |                 |   |   |   |   |    |    |    |   |    |    |    |    |    |       |
| Buszard et al. (62)         | 1               | 1 | 1 | 1 | 0 | 1  | NR | NR | 1 | 1  | 0  | 1  | 0  | 0  | 8     |
| Caserta and Singer (63)     | 1               | 1 | 1 | 1 | 1 | NR | NR | NR | 1 | 1  | 0  | 1  | 1  | 0  | 9     |
| Chang and Qiu (64)          | 1               | 1 | 1 | 1 | 0 | NR | 1  | 1  | 1 | 1  | 1  | 1  | 0  | 1  | 11    |
| Cowden (65)                 | 1               | 1 | 1 | 1 | 1 | 1  | NR | NR | 0 | 1  | 1  | 1  | 1  | 1  | 11    |
| Dimic et al. (66)           | 1               | 1 | 1 | 1 | 0 | 0  | NR | NR | 1 | 1  | 1  | 1  | 0  | 1  | 9     |
| Féry and Crognier (67)      | 1               | 1 | 1 | 1 | 0 | 0  | NR | NR | 1 | 1  | 0  | 1  | 0  | 0  | 7     |
| Fitzpatrick et al. (68)     | 0               | 1 | 1 | 1 | 1 | 1  | NR | NR | 1 | 1  | 0  | 1  | 1  | 1  | 10    |
| Garcia-Gonzalez et al. (69) | 1               | 1 | 1 | 1 | 0 | 1  | NR | NR | 1 | 1  | 0  | 0  | 0  | 0  | 7     |
| García-González et al. (70) | 1               | 1 | 1 | 1 | 0 | 1  | 1  | NR | 1 | 1  | 1  | 1  | 1  | 0  | 11    |
| Gimenez-Egido et al. (71)   | 1               | 1 | 1 | 1 | 0 | 1  | 1  | NR | 1 | 1  | 1  | 0  | 1  | 1  | 11    |
| Kolman et al. (72)          | 1               | 1 | 1 | 1 | 1 | 1  | 1  | 1  | 1 | 1  | 0  | 1  | 1  | 0  | 12    |
| Kovalchik and Reid (73)     | 1               | 1 | 1 | 1 | 1 | NR | NR | NR | 1 | 1  | 1  | 1  | 1  | 0  | 10    |
| Raschke and Lames (74)      | 1               | 1 | 1 | 1 | 1 | 1  | NR | NR | 1 | 1  | 0  | 1  | 1  | 0  | 10    |

NR, not registered; 1 = meet criteria; 0 = does not meet criteria; Questions = (1) Was the aim of the study stated clearly? (2) Was relevant background literature reviewed? (3) Was the design appropriate for the research question? (4) Was the sample described in detail? (5) Was sample size justified? (6) Was informed consent obtained? (7) Were the outcome measures reliable? (8) Were the outcome measures valid? (9) Were results reported in terms of statistical significance? (10) Were the analysis methods appropriate for the research design? (11) Was practical importance reported? (12) Were conclusions appropriate given the study findings? (13) Are there any implications for future research given the results of the study? (14) Were limitations of the study acknowledged and described by the authors?

responses by receivers compared to undisguised strokes and are significantly more effective than undisguised strokes in gaining a point or advantageous position. The authors suggest that this area should be included in the technical-tactical training of junior players.

The differences in the tactical knowledge of novice and entry professional tennis players were investigated by Garcia-Gonzalez et al. (69). They used the protocol of McPherson and Thomas to analyse the verbal reports during the game. They found significant differences in terms of conceptual content, structure, and sophistication. Entry professional tennis players had greater, more sophisticated, and differentiated tactical knowledge; more complex structures are developed in long-term memory with increasing experience. Specific tactics training can improve the tactical knowledge and cognitive skills of tennis players.

The study by Kolman et al. (72) is one of the few to have investigated the reliability, validity, and feasibility of an instrument for the integrated tactical-technical analysis of tennis players. They studied young tennis players at elite I and sub-elite (SE) level and found that tennis players at elite level had a better speed-accuracy index, higher average speed and accuracy and a lower percentage of errors in their game than tennis players at sub-elite level. They concluded that the test instrument has reasonable reliability and validity and is of practical value to tennis coaches.

The latest article by Fitzpatrick et al. (68) investigated how court size and ball type affect the performance of young tennis players. The results showed several specific adaptations to playing characteristics on different courts and balls (MR—red, MO—orange, MG—green, B—normal). MTR rallies were longer than FB ball rallies, and a higher percentage of forehands were played. The percentage of successful first serves was higher on MTR than on the other courts. The percentage of errors, double faults and net play was lower on MTR than on the other courts. The results suggest that a gradual transition from smaller courts to

full-size courts and the use of appropriate balls is necessary for the optimal development of younger tennis players' game.

## Game situations

Two studies investigated game situations in tennis matches, and both were of good methodological quality. The first study (64) analysed the matches of two elite tennis players based on the assessment of tennis coaches and established a classification model that incorporated the players' playing status, hitting habits and tennis skills, which formed the basis for the matches in which the notation analysis and decision tree algorithm were used. The study proved that integrated analysis of tennis games at the highest level is possible with the help of modern technologies, which can be used for imaginary training of other players so that players can gain experience through continuous simulation of training and game analysis.

The second study (67) investigated perceptual anticipation in realistic, meaningful situations and showed that the essential anticipatory information is contained in the view of the opponent's stroke movements, regardless of the tactical significance of the situation. The authors recommend a comprehensive analysis of tennis play and more ecological test conditions. However, no statistical tests were conducted to confirm these visible differences.

## Match performance

Three studies analysed match performance in tennis. One of these studies was of high methodological quality, and two studies were of good methodological quality. Kovalchik & Reid (73) analysed a large number of match and stroke performance indicators of elite junior players during matches and determined the effects on performance in professional and junior tennis. Professional players had a greater serve advantage, professional men and women won more points on serve as a percentage,

TABLE 3 Characteristics of the 13 studies reviewed technical-tactical skills, match situations and performance.

| Author                      | Sample size, sex                                       | Age (years) ± SD   | Level of performance, playing experience (years), number of participants | Measure(s) of skill(s)  | Results  |
|-----------------------------|--|--|--|---|--|
| Buszard et al. (62)         | Study 1: 7 male, 2 female<br>Study 2: 8 male, 8 female | Study 1: 17.1 ± 3.0<br>Study 2: male 12.1 ± 0.4; female 12.1 ± 0.9 | Study 1: N (n = 9)<br>Study 2: N (n = 16)                                | Study 1: Video clips were used to observe 1) the type of tennis shot type, 2) the side of the serve, and 3) the placement of the serve, and to detail the variability between skills and within skills during training. Study 2: Observing the effect of contextual interference (CI) on serve learning in “blocked” (low CI) and “serial” (moderate CI) practice conditions. | Study 1:<br>6 of 9 players = no differences between-skill variability in serve<br>Within-skill variability: placement > side<br>Accuracy: correlations: between-skill variability ( $r = 0.15$ , $p = 0.26$ ), within-skill variability ( $r = 0.16$ , $p = 0.24$ ). Study 2:<br>% of hits to target: moderate CI > low CI<br>% serves in: no differences<br>Serve displacement to T: low CI pre-test < post-test<br>Speed: no differences |
| Caserta and Singer (63)     | 59 male & female                                       | 21.75 ± 4.96   |  | To determine the effects of situation awareness (SA), anticipation (ANT) and decision making (DM) on the perceptual abilities of players in experimental (EG) and control (CG) groups.  | SA, A, DM practice improve performance<br>Response speed: E < C<br>Accuracy DM score: E < C<br>No differences in implicit and explicit learning strategies   |
| Chang and Qiu (64)          | 2 male (Roger Federer, Rafael Nadal)                   | RF = 26–38<br>RN = 21–33   | HP (n = 2)   | Development of an expert system for decision making in tennis matches, in which tennis coaches evaluate the tactical-technical skills of tennis players and a classification model was developed using notation analysis and the decision tree algorithm.   | Classification accuracy of the C5.0 algorithm > Qiu’s method<br>Highest scored strokes: baseline forehand and backhand, midcourt backhand  |
| Cowden (65)                 | 43; male = 25, female = 18                             | 13.6 ± 2.4   | N (12-and-under = 8; 14-and-under = 18; 16-and-under = 8, older = 9)     | Participants completed the mental toughness (MT) inventory and the scores recorded during a tennis match were used to create performance indices for each athlete.  | MT significantly correlated with ranking, match outcome, % of three or more consecutive points won per game, ratio of break points, % of points won when scores were level on serve and return, % of serve points won when ahead, % of return points won when behind.  |
| Dimic et al. (66)           | 2 male (Roger Federer, Novak Djokovic)                 | RF = 38<br>ND = 32   | HP (n = 2)   | Analyze how the efficiency and frequency of disguised (DIS) and undisguised (UND) strokes effect on players in rallies.   | Proportion of disguised strokes: RF > ND<br>Winning a point: DIS > UND<br>incorrect reactions of player: DIS > UND   |
| Féry and Crognier (67)      | 7 male   | 24.8   | A (n = 7)  | Monitor anticipatory cues to accurately estimate the spatio-temporal characteristics of the 4 different trajectories of incoming balls in 3 tactical situations.  | Error: Video < <i>in situation</i><br>Confidence estimations ≠ temporal estimations  |
| Fitzpatrick et al. (68)     | 48 male  | MTR = 7.4 ± 0.6; MTO = 8.5 ± 0.6, MTG = 9.9 ± 0.4; FB = 13.7 ± 0.5 | MTR (n = 18); MTO (n = 16); MTG (n = 8); FB (n = 6)                      | Determining the influence of court size scaling and ball modification tasks on the development of playing behavior in young tennis players on red (MTR), orange (MTO), green (MTG) and full court (FB).   | Rally length: MTR > MTG, FB % forehands: MTR > MTO, MTG, FB % backhands: MTR < MT, MTG, FB % net play: MTR < FB % errors: MTR < FB % first serve: MTR > MTO, MTG % Aces: MTG > MTR, MTO, FB  |
| Garcia-Gonzalez et al. (69) | 12 male  | HP = 16.1 ± 2.3; A = 16.3 ± 2.3                                    | HP (n = 6), A (n = 6)  | Evaluation of differences in tactical knowledge between high-performance players (HP) and advanced players (A) based on oral reports.   | tactical knowledge: HP > A<br>complex structures: HP > A<br>long-term memory: HP > A   |
| García-González et al. (70) | 11 male  | CG = 12.83 ± 0.75<br>EG = 13.00 ± 0.71                             | CG = 6 (3.67 ± 0.52)<br>EG = 5 (3.60 ± 0.54)                             | Evaluation of the effects of a decision training program on the decision-making ability and performance of tennis players (CG—control group; EG—experimental group).  | % successful decisions: EG > CG<br>execution skills: EG > CG   |
| Gimenez-Egido et al. (71)   | 20 male  | 9.46 ± 0.66  | Tennis experience = 3.65 ± 1.53  | Analysis of tennis players’ serve performance in two tournament formats (GC—green, modified court—MC).  | % first serve success: MC > GC<br>% aces: MC > GC<br>% unreturned serves: MC > GC<br>% net errors: GC > MC   |
| Kolman et al. (72)          | 32 male  | 13.4 ± 0.5   | Elite (n = 15)–Sub-elite (n = 17)  | Development of a reliable, valid and feasible technical-tactical test that can be used to identify and promote talent in tennis.  | velocity- accuracy-index: E > SE<br>mean velocity: E > SE<br>mean accuracy: E > SE<br>% errors: E < SE   |
| Kovalchik and Reid (73)     | 33 male–27 female                                      | HP = 23.0–24.2<br>J = 17.1–17.5                                    | HP (n = 42)<br>J (n = 18)  | Description of the age and performance profile of elite junior tennis players, comparison of match, game and stroke characteristics and comparison of the match factors most strongly associated with match wins in junior (J) and professional tennis (HP).  | Rally length: HP > J<br>Shot speed: HP > J<br>Speed at baseline: HP > J<br>Net clearance: HP > J<br>Sideline distance (FH): HP < J<br>Sideline distance (BH): HP < J<br>Distance from baseline (FH): HP > J<br>Distance from baseline (BH): HP < J   |
| Raschke and Lames (74)      | 24 male  | 10–14  | CG = 12<br>EG = 12   | Development of a video tactics training program for young top tennis players and testing of its effectiveness.  | Serving: EG > CG<br>Receiving: EG > CG–Baseline game: EG > CG<br>Preparation & finish: EG > CG   |

RF, Roger Federer; RN, Rafael Nadal; ND, Novak Djokovic; HP, high performance player; A, advanced player; N, national level player; J, junior; CG, control group; EG, experimental group; MTR, red court/ball; MTO, orange court/ball; MTG, green court/ball; FB, full court/normal ball; FH, forehand; BH, backhand; CI, contextual interference; SA, situation awareness; ANT, anticipation; DM, decision making; MT, mental toughness; DIS, disguised stroke; UND, undisguised strokes.

converted more break points, and executed more powerful and accurate shots than juniors. Professional men did 50% more work overall in the game than juniors, and junior women did 50% more work than professional women. The conclusions showed that the demands of the game and the physical characteristics of the shots differ between juniors and professionals.

The playing characteristics and indicators of serve performance of young tennis players playing with green and orange balls and on a suitable court were compared by Gimenez-Egido et al. (71). The conditions set by the young tennis players (court size, net height, ball type) have a significant influence on the observed game characteristics (e.g., length of rallies) and performance indicators (e.g., number of aces). Two studies investigated the psychological characteristics of a tennis game under competitive conditions.

In their study, Cowden (65) investigated the relationship between mental strength and performance measures in tennis. As expected, the results show a positive influence of mental strength on successful performance in competitive tennis (e.g., ranking, match outcome, follow-up points won,...), especially in certain match situations. Only in this study were statistical tests performed to confirm a significant correlation.

## Discussion

The aim of this review was to provide an overview of the research on technical and tactical competencies to define the different levels of play in the game of tennis. The intention was to explore the possibilities that the competencies and the competency model approach offer for the description, identification and differentiation of tennis playing levels and, eventually, to pave the way for the creation of a model framework that would assist in the further development of a competency-based model applied to tennis. Not studies have been found that comprehensively address tactical effectiveness and technical efficiency and analyse the level of play or the performance of tennis players by their competence as a combination of skills and knowledge application. In this review, a number of studies have been found in which skills are used instead of competences, which is a subordinate concept. As indicated above, the term competence includes skills, behaviours, knowledge, and abilities that enable a player to perform certain actions effectively in sport.

Competency-based models have also been used in areas other than analysing athlete performance in the study of Fletcher and Maher (75), in which they developed a competency model and its implications for applied sport psychology and professional development and lifelong learning in applied sport psychology. For the sport management, Toh and Jamieson (76) construct and validate a survey instrument to determine and develop of sport management competencies and model. The analysis of coaches' competencies in team sports in four areas (motivation, game strategy, technique and character-building competencies) showed that improving coaches' psychological and tactical skills and their ability to recognize skills, together with a positive attitude towards sport, can help to improve athletes' confidence in the

work of coaches (77). Lim et al. (78) found that the competence levels of coaches did not differ significantly by gender and performance of student athletes, but did differ significantly by sport type, between team and individual sports. The competency model proved to be a useful tool for sports organizations to identify and recruit coaches and for coaches to apply coaching planning strategies to ensure the effectiveness of their work. In reviewing the literature, we have not found any articles that would design a competency model to determine the level of play, important skills, and performance indicators in tennis, or we have only found attempts to design a model in a narrower field of research.

Studies analysing inter-skill variability during practice found that skilled tennis players generally perform serve drills with little contextual interference. The differences were influenced by the direction of the serve (placement) and the side from which the serve was executed, but no differences were found in terms of percentage of hits, displacement of the serve and speed (62). Whiteside et al. (79) concluded that there are no differences in body kinematics between successful serves and serve faults. Serves into the net are characterized by projection angles that are significantly further below the horizontal. They conclude that the coordination of the distal degrees of freedom and a sophisticated coupling of perception and action appear to be more important for success than any isolated mechanical component of the serve. Other conclusions were reached by Antunez et al. (80), who found that an increase in movement variability can have a negative effect on serve performance in tennis by reducing the speed and accuracy of the ball. Meanwhile, Whiteside et al. (81) investigated the coordinated joint rotations and variability of the lower limbs, trunk, service arm and ball position during the serve of elite female tennis players. The coordinated joint rotations of the lower limbs and trunk appeared to be most consistent at the time the players left the ground. The variability in the two degrees of freedom of the elbow became significantly greater as the serve approached. Despite the variable ball throw, the temporal composition of the serve was very consistent, supporting previous claims that players use the position of the ball to regulate their movement.

Two studies investigated the effectiveness of a decision training program and specific instructions on decision making and performance in tennis. They found positive effects of the program on game performance, reaction speed, accuracy (63) and the percentage of successful decisions (70). García-Gonzalez et al. (82) found in an earlier study a positive characteristic correlation between tennis players' knowledge, decision-making during the serve and the decision-making aspects that tennis players develop during the game. Decision making in tennis is also closely linked to cognitive perceptual abilities, including anticipation. Caserta et al. (83) confirmed that training of perceptual-cognitive skills resulted in significantly faster reaction time, a higher percentage of accurate responses and a higher percentage of performance decisions. García et al. (84) showed differences in tactical knowledge, which is more structured and sophisticated than the declarative and procedural level of elite tennis players.



The model of decision training developed by Vickers (85) explains the building of tactical experiences that promote the development of tactical knowledge and cognitive skills, including the training of cognitive skills related to decision making. The mentioned model was used by García-González et al. (70) and confirmed the usefulness of a combination of different tools such as video feedback or questions as explicit learning methods and can achieve improvements for highly complex situations. By applying the decision training model, tennis players were able to significantly improve their decision making and game performance and maintain these improvements during the retention phase. Vernon et al. (86) investigated the individual contribution of kinematic or contextual information sources to the anticipation ability of an experienced athlete in a time pressure situation, when returning a serve. They used a qualitative interview methodology to investigate this interaction. The results support previous work that has independently examined the different anticipatory sources of information available to a tennis player and the fact that players weight or prioritize certain information under certain circumstances. Otherwise, essential anticipatory information, regardless of the tactical significance of the situation, is contained in the view of the opponent's stroke movements (67). Garcia-Gonzalez et al. (69) investigated tactical knowledge, specifically the problem of strategic planning and found significant differences in conceptual content, complex structure, long-term memory and sophistication between professional and advanced tennis players. Raschke and Lames (74) also used the method of video-based tactics training and confirmed significant improvements in cognitive abilities in the interpretation of tactical behaviour in practice and matches. As shown in previous studies, specific training programs can improve the tactical knowledge and level of cognitive skills of tennis players by creating a relevant knowledge base that increases with experience and expertise. The inclusion of specific program to improve tactical skills and decision making should be present at different stages of skill development so that significant improvements in cognitive, behavioural, and performance-related variables could occur.

Athletes' anticipation is based on contextual cues resulting from the opponent's movement towards the strike position and from the opponent's posture prior to impact (87). Advanced players can pay attention to these cues and obtain detailed and reliable information about when to expect a hit. On the other hand, they tend to "disguise" their intention to hit, which confuses their opponent's assessment and impairs their anticipatory reaction. Hiding the intention is a very specific skill that allows for greater unpredictability at the level of top tennis players and at the same time creates a tactical advantage for the player and a disadvantage for the opponent (66).

In tennis, great importance is given to psychological aspects, especially at the higher performance level. One component of mental strength that is particularly relevant in sport, especially in tennis, is the control of thoughts and emotions. In reviewing the literature, we excluded only one study from the psychological domain, which certainly does not reflect the importance, but rather the complexity of the domain and the difficulty of

analysing it under competitive conditions. Cowden (65) notes that mental toughness appears to depend on the nature of the performance area and the context of the game and that it is impossible to address this area independently of the physical, technical, tactical and psychological characteristics of athlete and opponent.

As per the practical application of this study, the tools identified in this systematic review are important for analysing how coaching and competition conditions can be adapted for young athletes. Designing effective sport tasks and competitions for young athletes is a complex process in which many factors interact in the learning of functional skills and behaviours. Reducing the height of the net and the size of the court improves serving performance and thus creates a useful learning environment for young tennis players (71). Adapted training and playing conditions for young tennis players influence many performance indicators such as the length of rallies, the variety of strokes and the success of the serve (68), the number of winners, forced errors, volleys played, the height of the stroke impact zone and the player's position on the court (88), as well as the style of play (89).

In match play scenarios, for the performance or notation analysis of the tennis game, in addition to the already established visual or video analysis, artificial intelligence methods have recently been used more frequently. These methods enable the analysis of a large amount of data on the players' stroke and movement techniques, the trajectories and landing points of the balls and the general observation of both tennis players during the match. Chang and Qiu (64) analysed two elite tennis players and, together with tennis experts, developed a decision tree algorithm that took into account game results, hitting habits and tennis knowledge. The use of this decision-making system is a useful tool for comprehensive and detailed analysis as well as a training tool for tennis players to gain experience. The tactical-technical instrument, analyses tennis players in different tactical situations (i.e., offensive, neutral and defensive), is a reliable, valid and practicable test that, in addition to analysis, enables the identification of talent and the long-term development of young tennis players (72). An equally valid and reliable tool for monitoring the content of technical-tactical training sessions on courts was developed by Penalva et al. (90), which allows tennis coaches to improve the planning and programming of on-court training in order to contribute more efficiently to the development of players, regardless of their level of play.

It is therefore realistic to use artificial intelligence methods based on the mining of event sequences to make it possible to summarize a large number of different patterns, constant interdependencies in the performance of both athletes, multivariate strokes and movements, and positions on the court, which are common to all racket sports (91).

Therefore, the application of a competency model in tennis is possible if an integrated approach is chosen for the problem to be addressed and an appropriate amount, accuracy and depth of data is available. Currently, this is only possible with automatic motion tracking systems such as Hawk-Eye. With the system it is possible to identify the similarities and differences in the stroke

and movement characteristics of different groups of tennis players (i.e., men, women, professionals, juniors). Kovalchik and Reid (73) with the method of data collection, the selection of performance indicators and the methods used to analyse and present the data comes closest to a holistic view of match play. Such an approach is the basis for the creation of a competency model and thus also a tool to understand how competitiveness, playing demands and physical characteristics of strokes differ between quality groups of tennis players.

There are several limitations of this study that can be mentioned. First, a methodology based on Law et al. (61) was used for this systematic review, in which two experts independently rated the quality of the selected articles. Since the experts' ratings differed slightly, the average scores were calculated. Secondly, there are several technical limitations in the comprehensive analysis of tennis when addressing several important areas simultaneously. The technical limitations of collecting data on players during matches influence the researchers' decision to choose only a narrower range of observations to analyse the game. All this leads to a lack of studies examining tactical and technical skills/competencies, psychological functioning, and fitness during a tennis match. With the advent of modern technologies, machine learning and artificial intelligence, the possibilities for a comprehensive analysis of tennis play during the match and for determining the individual quality level of tennis players will increase. At the same time, tennis experts must use modern technologies to create theoretical models that form the basis for testing skill-based models. Only in this way will it be possible to transfer theoretical knowledge into practice.

## Conclusions

As it has been stated, success in tennis is a multifaceted concept that transcends mere victory on the court; it encompasses personal growth, achievement of individual goals, and recognition within the broader tennis community.

The number of articles dealing with tennis under real conditions and linking individual narrower areas of research (such as tactics and technique) is currently quite small. In addition to analyzing individual factors that influence the efficiency and effectiveness of tennis players, it is necessary to look for interactions between individual areas and factors. It is precisely the search for reciprocal relationships between factors that enables a more precise insight into the tennis game and the performance of tennis players. In addition, the use of competency models enables the analysis of complex sports such as tennis.

The complexity and dynamics of the game of tennis should not be an obstacle to comprehensive research and application of the competency model in this area. Future lines of research could consider the creation of competency models of tennis levels of play that could include, at least, three key elements: (1) key competencies, (2) description of standards, (3) evidence. The development of tennis competency models for different

quality and age groups, both genders and individual game situations must initially take place at the level of evidence or performance indicators. In the following, the models must be supplemented by a description of standards and key competencies for the tennis player groups mentioned. There are already some attempts to determine the competencies for different age and quality levels of tennis players, but only at expert level and they have not been published and verified with scientific methods. For a better understanding, an example of the competence of a young female tennis player is provided: "When playing at the baseline, the player shows that she is able to play appropriate strokes depending on the opponent's stroke quality and taking into account her placement." Similarly, in the future it will be necessary to create theoretical competence models and test them using both scientific methods and practical tests.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Author contributions

MC: Conceptualization, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. RM-G: Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. AF: Conceptualization, Data curation, Formal Analysis, Investigation, Software, Writing – original draft, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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