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Training interventions and physical performance adaptations in youth tennis players: a systematic scoping review

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Abstract

Background and Study Aim Youth tennis performance depends on the development of multiple physical domains, including speed, agility, power, accuracy, and endurance. Although numerous training interventions have been proposed, the evidence base is heterogeneous. Certain domains, particularly accuracy and endurance, remain underexplored. A structured mapping of existing interventions is therefore needed to inform evidence-based training practice. This scoping review aimed to systematically map and synthesize the effects of structured training interventions on key performance domains in youth tennis players (⩽19 years).

Material and Methods A systematic scoping review was conducted in accordance with PRISMA 2020 guidelines. Five electronic databases (PubMed, Scopus, Web of Science, SPORTDiscus, and Cochrane CENTRAL) were searched for studies published between January 2015 and August 2025. Eligible studies included randomized controlled trials, quasi-experimental designs, and single-group pre–post interventions examining structured training programs in youth tennis players. Outcomes were categorized into five domains: speed, agility/change of direction, power, accuracy, and endurance. Risk of bias was assessed using RoB 2.0 and ROBINS-I. Reporting quality was evaluated using the CERT checklist.

Results Twenty-five studies met the inclusion criteria. Plyometric training, high-intensity interval training (HIIT), functional and neuromuscular training, core stability programs, resisted sprinting, and flywheel-based resistance training demonstrated significant improvements in at least one performance domain. Speed, agility, and power showed the most consistent and robust improvements across interventions. HIIT and repeated-sprint programs produced the largest endurance gains. Balance improvements were commonly observed following core and neuromuscular training. In contrast, serve and stroke accuracy outcomes were inconsistently reported and showed limited responsiveness. Overall risk of bias was low to moderate, with more recent studies demonstrating higher reporting quality.

Conclusions Structured, multi-component training interventions effectively enhance key physical performance domains in youth tennis players, particularly speed, agility, and power. However, evidence for accuracy and endurance remains limited. Future research should prioritize standardized outcome measures, longer follow-up periods, and integrated training models to optimize performance development in youth tennis.

Keywords: youth tennis players, training interventions, speed and agility, muscular power, endurance performance.

Introduction

Youth tennis performance is influenced by the combined development of several physical capacities that underpin effective movement, stroke execution, and repeated efforts during match play. Training programs for young players commonly target speed, agility, power, accuracy, and endurance, as these qualities contribute differently to on-court performance. The impact of training on these domains varies depending on the type and structure of the intervention, as well as the specific physical qualities emphasized within a program. Therefore, the examination of how different structured training approaches affect distinct performance domains

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provides a basis for interpreting training-related adaptations in youth tennis.

Tennis is a high-intensity intermittent activity that imposes significant technical, tactical, psychological, and physical demands on players [1]. Tournament performance in tennis is determined by the interdependence of these domains, with technical execution, tactical awareness, psychological resilience, and physical conditioning forming an integrated framework that supports success in competition [2, 3]. Extensive research has examined the physiological and tactical requirements of match play in tennis and has provided insights into the sport's complex performance profile. Studies consistently indicate that players are exposed to frequent accelerations, decelerations, and multidirectional changes during rallies. These actions are interspersed with recovery phases, which together characterize tennis as an intermittent high-intensity sport [4, 5, 6]. Such demands require well-developed strength, power, endurance, agility, and precision, which directly influence players' ability to perform under competitive pressure. At the youth level, competitive success depends on the integration of physical and cognitive components within a coherent developmental model [2, 3]. The long-term athletic development of youth tennis players is underpinned by the systematic progression of physical capacities that support on-court skill. This principle reflects a structured, age-appropriate, and biologically grounded approach to training, taking into account individual maturation and periods of trainability rather than chronological age alone [7, 8]. Among these capacities, speed, agility, power, accuracy, and endurance are considered foundational domains influencing competitive success.

Recent meta-analyses synthesizing data from more than 8000 competitive youth players indicate clear normative values for these capacities, which can guide benchmarking and individualized training prescriptions [9]. However, these values also underscore the variability across developmental stages and the need for training interventions tailored to age, maturation, and competitive level. For example, speed is not only relevant for covering the court effectively but is also strongly linked to tactical execution and shot preparation. Agility, encompassing change-of-direction (COD) and reactive quickness, is even more tennis-specific, as points frequently involve rapid multidirectional movements [10]. Power, in both the upper and lower body, translates directly into serve velocity, explosive strokes, and the ability to recover between movements [11, 12]. Accuracy underpins stroke precision, while endurance ensures sustainable performance across matches and tournaments. Each of these domains is trainable, but the efficacy of training depends on evidence-based program design.

A diverse range of training interventions has been studied in youth tennis populations. Plyometric training has consistently improved jump performance, sprint times, and agility. However, its effects on stroke accuracy remain equivocal [13, 14]. Core stability training enhances serve velocity, balance, and agility, with dynamic programs often outperforming static approaches [15, 16, 17]. High-intensity interval training (HIIT) has emerged as a potent method to improve aerobic endurance and explosive performance. Recent trials have reported improvements in sprint speed, agility, and VO_2max among adolescent players [18, 19]. Evidence also supports specific training modalities, including plyometrics, neuromuscular training, functional drills, and HIIT, for enhancing these physical domains [20, 21]. Neuromuscular training (NMT) integrates coordination, balance, and movement control with physical conditioning and has shown benefits in younger cohorts [21]. Functional and skill-based training programs have demonstrated superiority over traditional conditioning in enhancing agility, power, and movement quality [22, 23]. More recently, flywheel resistance training has been applied in tennis, with promising results for explosive strength and change-of-direction agility [24, 25].

In parallel, innovative tools such as virtual reality-based swing analysis and skill fitness training modules are being explored, although the available evidence remains preliminary [26]. These developments underscore the rapidly evolving training landscape. This situation necessitates systematic efforts to collate and evaluate training interventions. While individual studies demonstrate meaningful improvements in performance outcomes, the evidence base remains fragmented. Several reviews have addressed tennis conditioning more broadly. However, many are limited by heterogeneous populations, including adult players, a lack of focus on youth athletes, or a narrow scope of outcomes. For example, a recent review by Fleming et al. [27] synthesized training and match-play demands in junior players but did not map intervention outcomes across specific performance domains. Similarly, the meta-analysis by Wang et al. [12] on neuromuscular training confirmed improvements in serve velocity and agility. However, it did not address the breadth of other training modalities. Furthermore, serve and stroke accuracy, despite being critical determinants of competitive success, remain underrepresented in training intervention studies. Reported improvements in these outcomes are far less consistent than those observed for speed or power [11, 28]. Similarly, although functional and technology-assisted training approaches are gaining popularity, evidence regarding their long-term effectiveness in youth tennis populations remains limited [29, 30].

Despite the growing body of literature

examining physical conditioning in tennis, existing reviews have largely focused on adult or mixed-age populations, isolated training modalities, or single performance outcomes. As a result, they provide limited guidance for evidence-based decision-making in youth tennis. Moreover, under-researched yet performance-critical domains such as accuracy and balance remain marginal within current syntheses, despite their relevance to technical consistency, movement efficiency, and long-term athlete development. Therefore, beyond merely cataloguing interventions, an integrative synthesis is required. Such an approach allows systematic mapping of which training modalities influence specific performance domains, how these effects vary across developmental stages, and where substantive evidence gaps persist. Accordingly, this systematic scoping review aims to map and critically synthesize structured training interventions applied in youth tennis players (⩽19 years) over the last decade. A domain-specific framework encompassing speed, agility, power, accuracy, endurance, and balance is applied. Through this approach, the review seeks to (i) identify modality–outcome relationships across performance domains, (ii) highlight underrepresented and emerging areas such as accuracy- and balance-oriented training, and (iii) provide a conceptually informed foundation to support practitioners in designing developmentally appropriate, evidence-based training programs for youth tennis athletes.

Methodology

Protocol and reporting framework

This scoping review was conducted in accordance with the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [31], as described by Page et al., ensuring transparency, methodological rigour, and reproducibility throughout the review process. The review was not prospectively registered in databases such as PROSPERO. This approach aligns with common practice for scoping reviews, where the primary aim is to map and synthesize available evidence rather than to provide a definitive effect estimate.

The overarching aim of this review was to map and critically synthesize evidence from the last decade (2015–2025) on structured training interventions in youth tennis players and their effects on key performance domains. To structure the review question and eligibility process, the PICOS framework was applied [30]. Population (P): youth and adolescent tennis players aged ⩽19 years, across all competitive levels and both sexes. Interventions (I): structured training or conditioning programs, including but not limited to plyometric training, core and stability programs, high-intensity interval training (HIIT), resisted and unresisted sprinting, functional or neuromuscular training, strength training, balance training, and agility or change-of-direction protocols. Comparators (C): any comparator, including active control conditions (usual tennis training), alternative training modalities, or no-intervention control groups. Single-group pre–post studies were included, given the scoping nature of the review.

Outcome Measures and Study Design

Eligible studies were required to report outcomes in at least one of five pre-specified performance domains: speed (e.g., 5–20 m sprint tests and split times); agility or change of direction (COD) (e.g., 505 test, T-test, Illinois test, pro-agility shuttle, and reactive agility drills); power (e.g., countermovement jump [CMJ], squat jump [SJ], drop jump [DJ], standing long jump [SLJ], reactive strength index, medicine-ball throws, and serve velocity); accuracy (e.g., serve or stroke precision tests); and endurance (e.g., Yo-Yo Intermittent Recovery tests IR1 and IR2, 20 m shuttle run, VO_2max, or tennis-specific intermittent endurance assessments).

With respect to study design, randomized controlled trials (RCTs), quasi-experimental controlled trials, and single-group pre–post intervention studies were included. In addition, peer-reviewed conference abstracts were considered eligible when sufficient detail on the training intervention and relevant performance outcomes was reported. This approach was consistent with the scoping nature of the review.

Intervention Characteristics and Replicability Framework

To enhance methodological transparency and replicability, intervention characteristics were extracted using the FITT principles (frequency, intensity, time, and type), in alignment with the Consensus on Exercise Reporting Template (CERT). Where reported, training frequency, duration, session length, exercise type, intensity prescription, progression, and rest intervals were documented to enable structured comparison across interventions. Participant characteristics relevant to replication, including age, sex, competitive level, baseline training status, and maturation indicators, were extracted when available. Outcome assessment protocols were summarized by performance domain, including test type and instrumentation, to improve the interpretability of measurement approaches. Statistical methods used across studies, such as group × time analyses and effect size reporting, were recorded descriptively. Consistent with scoping review methodology, heterogeneity was addressed through narrative synthesis rather than quantitative pooling.

In addition, participant characteristics relevant to replication were systematically extracted across studies, including age, sex, competitive level, baseline training status, and inclusion and exclusion criteria. Indicators of biological maturation (e.g., prepubertal, pubertal, adolescent classification, or age-based grouping) were documented when available to contextualize training responsiveness across developmental stages. Given inconsistent reporting across studies, missing participant-level details were explicitly noted and considered during the interpretation of findings rather than excluded.

Statistical approaches used in the included studies were summarized descriptively, including study design (RCT, quasi-experimental, pre–post), use of group × time analyses, repeated-measures models, post hoc comparisons, and effect size reporting. Where reported, approaches to missing data and analytical handling were recorded. Consistent with scoping review methodology, methodological heterogeneity was managed through narrative synthesis and domain-based outcome mapping rather than statistical aggregation.

Eligibility criteria

Eligibility criteria for study inclusion were defined a priori to ensure consistency and transparency in the study selection process. These criteria were structured according to the PICOS framework and encompassed population characteristics, intervention types, comparators, outcome domains, study designs, and additional methodological constraints. A detailed overview of the eligibility criteria applied in this review is presented in Table 1.

Search strategy

The search strategy for this systematic scoping review was designed to be comprehensive and reproducible, ensuring the identification of all potentially relevant studies across major biomedical and sport sciences databases. Controlled vocabulary (e.g., MeSH in PubMed) was combined with free-text keywords to capture variations in terminology related to tennis, youth, training interventions, and the five pre-specified performance outcomes (speed, agility, power, accuracy, and endurance). Search terms were tailored to each database's indexing system but followed a common framework.

For example, the PubMed search strategy was: (tennis[Title/Abstract] OR racquet sport[Title/Abstract]) AND (youth OR adolescent* OR junior* OR teen* OR child* OR "young player*") AND (training OR intervention OR conditioning OR plyometric* OR "core training" OR "high-intensity interval training" OR HIIT OR "strength training" OR "neuromuscular training" OR "resisted sprint*" OR "functional training") AND (speed OR sprint OR agility OR "change of direction" OR COD OR power OR jump OR "medicine ball" OR "serve velocity" OR accuracy OR precision OR endurance OR "Yo-Yo"

Table 1. Eligibility Criteria for Inclusion of Studies

Domain	**Criteria**
Population (P)	Youth/adolescent tennis players (⩽19 years). Studies with mixed ages were included only if youth data were reported separately or comprised ⩾80% of the sample. Both sexes and all competitive levels (from novice to elite juniors) are eligible.
Interventions (I)	Structured training or conditioning programs to enhance tennis performance or underlying physical capacities, e.g., plyometrics, core/stability training, HIIT, resisted/unresisted sprinting, functional/neuromuscular training, strength training, flywheel/isoinertial, balance, agility/COD protocols.
Comparators (C)	Any: active control, usual tennis training, alternate training, or no-intervention control. Single-group pre-post designs are eligible given the scoping aim.
Outcomes (O)	At least one of five pre-specified performance domains: • Speed: Linear sprint (5-20 m) and split times • Agility (COD): 505, T-test, Illinois, pro-agility, reactive agility • Power: Jumps (CMJ, SJ, DJ), medicine-ball/overhead throws, serve velocity (power-skill), SLJ, RSI • Accuracy: Serve or stroke accuracy/precision tests • Endurance: Yo-Yo IR1/IR2, 20 m shuttle/VO_2max, tennis-specific intermittent tests
Study designs	RCTs, quasi-experimental controlled trials, and single-group pre-post designs. Conference abstracts included if they reported training interventions and relevant outcomes.
Time window	January 1, 2015 - August 31, 2025 (last 10 years from search date).
Setting	Any (on-court, gym/field, combined).
Language	English only.
Exclusions	Reviews, editorials, protocols, case reports; purely cross-sectional or acute single-session studies; rehabilitation/injury-only programs; non-tennis populations; no extractable outcomes in the five domains.

OR “VO2max”). Filters were applied for publication dates between January 1, 2015 and August 31, 2025, human participants, and English-language publications.

Equivalent strategies were adapted for Scopus, Web of Science, SPORTDiscus, and Cochrane CENTRAL to ensure coverage of biomedical, multidisciplinary, and sport-specific literature. Boolean operators (AND, OR), truncation symbols (*), and quotation marks were used to maximize retrieval sensitivity while maintaining specificity.

Additional hand-searching of reference lists and citation tracking via Google Scholar and ResearchGate were conducted to identify grey literature and conference abstracts meeting the inclusion criteria.

The eligibility criteria applied during the search and selection process, structured according to the PICOS framework, are summarized in Table 2 (FIgure 1).

Risk of Bias and Certainty of Evidence

By evaluating the study designs of the included studies, heterogeneity was observed. Fourteen studies were randomized controlled trials (RCTs), six were quasi-experimental trials with non-randomized allocation, and four were single-group pre–post designs. Accordingly, design-specific appraisal tools were employed. For RCTs, the Revised Cochrane Risk of Bias Tool for Randomized Trials (RoB 2.0) was used to evaluate the randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selective reporting. Each domain was rated as “low risk of bias,” “some concerns,” or “high risk of bias,” and these ratings were combined into an overall judgment for each study.

For non-randomized trials and pre–post designs, the ROBINS-I (Risk of Bias in Non-randomized Studies of Interventions) tool was applied. This tool covers confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. Two reviewers independently applied the appraisal tools. Discrepancies were resolved through consensus and, when necessary, consultation with a third reviewer.

To further assess the quality of exercise intervention reporting, the Consensus on Exercise Reporting Template (CERT), a 19-item checklist

Table 2. Eligibility criteria according to the PICOS conditions

Category	Inclusion Criteria	Exclusion Criteria
Population	Youth/adolescent tennis players (⩽19 years); both sexes; all competitive levels (novice to elite juniors). Mixed-age studies included if youth-only data were reported or ⩾80% of the sample were youth.	Adults (>19 years), non-tennis athletes, mixed sports samples without separate tennis data, and clinical or rehabilitation-only populations.
Interventions	Structured training or conditioning programs (plyometric, core/stability, HIIT, resisted or unresisted sprinting, functional or neuromuscular training, strength training, flywheel or isoinertial training, balance, agility or COD).	Acute single-session interventions, rehabilitation-focused therapies, injury-only prevention programs, or studies without a structured training program.
Comparators	Any: active control, usual tennis training, alternate training, or no-intervention control. Pre–post single-group designs included.	Studies lacking any comparator or baseline data; purely observational cross-sectional studies.
Outcomes	At least one of five pre-specified domains: Speed (5–20 m sprint); Agility (COD) (505, T-test, Illinois, pro-agility, reactive agility); Power (CMJ, SJ, DJ, SLJ, RSI, medicine-ball throws, serve velocity); Accuracy (serve or stroke precision tests); Endurance (Yo-Yo IR1 or IR2, 20 m shuttle run or VO_2max).	Studies not reporting performance outcomes in the five domains; outcomes limited to psychosocial, biomechanical, or injury-only metrics.
Study Design	RCTs, quasi-experimental controlled trials, single-group pre–post designs; conference abstracts if reporting interventions and outcomes.	Reviews, systematic reviews, protocols, editorials, commentaries, case reports, purely descriptive studies.
Time Frame	Published between January 1, 2015 and August 31, 2025.	Published before 2015 or after August 2025.
Setting	Any setting: on-court, gym or field, or combined.	Non-training laboratory-only simulations without real training protocols.
Language	English.	Non-English publications.
Other	Human participants only; sufficient data extractable.	Animal studies; insufficient or non-extractable data.

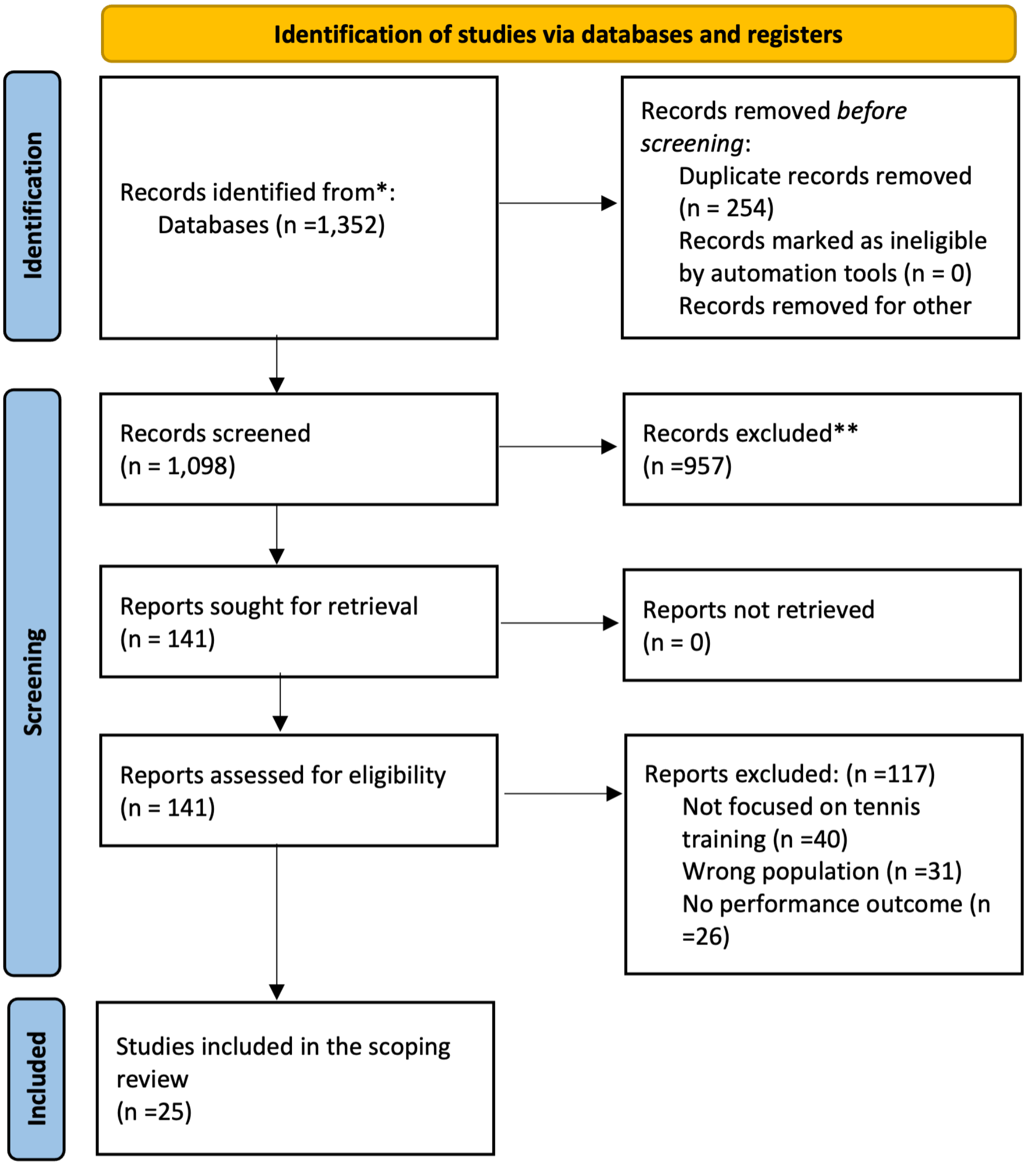

Figure 1. Flow diagram of the study selection

across seven categories, was applied to a subset of eligible trials. This approach ensured that exercise protocols (e.g., plyometric drills, HIIT formats, or core training routines) were described with sufficient detail to allow replication. Trials scoring ⩾9 were classified as having "high" reporting quality, whereas those scoring <9 were classified as "low." Overall, more recent trials published after 2020 achieved higher CERT scores, indicating improved transparency in exercise reporting compared with earlier studies.

The certainty of the body of evidence was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) framework, implemented with the GRADEpro online tool. Certainty was judged per outcome domain (speed, agility, power, accuracy, and endurance), considering risk of bias, inconsistency of training effects, indirectness, imprecision, and potential publication bias. The overall certainty ranged from low to moderate. Evidence for speed, agility, and power was rated as moderate, reflecting consistent improvements across multiple RCTs, although heterogeneity in test protocols was present. Evidence for endurance was rated as low to moderate due to smaller sample sizes and fewer trials directly targeting aerobic capacity. Evidence for accuracy was rated as low, as only a limited number of studies assessed stroke or serve precision and measurement methods varied widely.

All risk of bias and certainty assessments were performed independently by two reviewers, with confirmation by a methodological expert. Any disagreements were resolved through structured discussion. The resulting judgments informed the narrative synthesis and ensured that findings were interpreted in light of methodological strengths and limitations.

Results

A total of 25 studies met the inclusion criteria and were systematically reviewed. These studies investigated the effects of diverse training interventions, such as plyometric training, high-intensity interval training (HIIT), functional drills, core stability and strength programs, flywheel-based resistance training, balance protocols, and integrative neuromuscular training, on youth tennis players (⩽19 years). Across interventions, performance outcomes were mapped onto the five pre-specified domains: speed, agility, power, endurance, and accuracy.

The included studies demonstrated substantial heterogeneity in training modality, duration, participant characteristics, and outcome assessment. Therefore, results were synthesized using a domain-based mapping approach rather than quantitative pooling.

Table 3 provides a structured overview of the 25 included studies. It summarizes intervention type, duration, sample characteristics, testing protocols, and primary performance outcomes across speed, agility, power, endurance, balance, skill, and accuracy domains. This presentation enables comparison of modality–outcome relationships and highlights

Table 3. Study Characteristics of Included Studies (N = 25)

Sl. No.	Study (Authors, Year)	Training Intervention	Duration	Sample Size & Age	Tests Used	Improved Performance Parameters
1	Behringer et al. [11]	Plyometric vs machine RT + control	8 wks	36 males (~15 y)	Radar gun (serve velocity)	Power ↑ – Accuracy no change
2	Fernández-Fernández & Ellenbecker [28]	Multi-component conditioning vs control	6 wks	30 males (~13 y)	Radar gun (serve velocity)	Power ↑ – Accuracy no change
3	Fernández-Fernández et al. [33]	Explosive strength + RSA	8 wks	8 elite males (~17 y)	20 m sprint, CMJ, RSA test, Yo-Yo	Speed ↑ – Power ↑ – Anaerobic endurance ↑
4	Fernández-Fernández et al. [13]	Plyometric training vs control	8 wks	60 (12–13 y)	5–20 m sprint, 505 test, CMJ, SLJ, MB throw, radar	Speed ↑ – Agility ↑ – Power ↑ – Serve speed ↑
5	Kilit & Arslan [19]	HIIT vs tennis training	8 wks	20 (~15 y)	20 m sprint, agility drill, shuttle run	Endurance ↑ – Agility ↑ – Speed ↑
6	Yildiz et al. [22]	Functional vs traditional vs control	8 wks	28 (~9–10 y)	10 m sprint, T-test, vertical jump, Y-balance, FMS	Speed ↑ – Agility ↑ – Power ↑ – Balance ↑
7	Zirhli & Demirci [23]	Functional training (girls)	6 wks	24 (10–12 y)	20 m sprint, Illinois test, vertical jump, balance test	Speed ↑ – Agility ↑ – Power ↑ – Balance ↑
8	Arslan & Ergin [16]	Core training vs control	8 wks	20 (10–14 y)	Shuttle agility, MB throw, SLJ, skill test	Agility ↑ – Power ↑ – Skill ↑
9	Sannicandro et al. [32]	Balance training	6 wks	24 (~13 y)	Isokinetic strength symmetry, balance platform	Strength symmetry ↑
10	Ziagkas et al. [37]	Plyometric (conference study)	8 wks	20 (teens)	Tennis agility circuit	Agility ↑
11	Sinković et al. [14]	Plyometric vs control	8 wks	28 (~14 y)	505 COD, reactive agility test, CMJ	Agility ↑ – Speed ↑ – Power ↑
12	Novak et al. [25]	Plyometric bands vs machine	8 wks	30 (~16 y)	5–10 m sprint, T-test, CMJ, MB throw, radar	Speed ↑ – Agility ↑ – Power ↑ – Serve ↑
13	Canós et al. [24]	Flywheel vs machine vs control	8 wks	24 females (~15–17 y)	5–15 m sprint, COD 180°, CMJ, MB throw, radar	Speed ↑ – Agility ↑ – Power ↑
14	Bashir et al. [36]	Core stability vs control	6 wks	30 (~15 y)	505 test, Y-balance	Agility ↑ – Balance ↑

Table 3. Continued.

Sl. No.	Study (Authors, Year)	Training Intervention	Duration	Sample Size & Age	Tests Used	Improved Performance Parameters
15	Bangari et al. [41]	Core + plyometric	12 wks	17 (12–14 y)	Pro-agility, balance platform, vertical jump	Agility ↑ – Balance ↑
16	Ergin & Arslan [42]	Balance training vs control	8 wks	20 (15–19 y)	Pro-agility, vertical jump	Agility ↑
17	Wang et al. [40]	NMT + tennis vs tennis-only	8 wks	40 (~11 y)	10 m sprint, 505 COD, balance test	Speed ↑ – Agility ↑ – Balance ↑
18	Kocyigit et al. [38]	Combined training vs standard	6 wks	18 (~16 y)	Radar gun (serve speed), agility/endurance drills	Serve speed ↑
19	Terraza-Rebollo et al. [35]	Strength training	9 wks	16 (~16 y)	Radar gun (FH/BH velocity)	Stroke speed ↑
20	Shi et al. [43]	Rope jumping	12 wks	30 (13–15 y)	Dynamic balance test, hitting stability test	Balance ↑ – Skill ↑
21	Moya-Ramón et al. [39]	Resisted vs free sprint	6 wks	20 (~16.5 y)	5–20 m sprint, 505 COD, CMJ, SLJ	Speed ↑ – Agility ↑ – Power ↑
22	Chen [15]	Core stability vs conventional	6 wks	30 (~16 y)	Serve/smash speed, balance test, footwork test	Power ↑ – Balance ↑ – Agility ↑
23	Kızılca & Okut [17]	Core training	6 wks	30 (~14–16 y)	Radar gun, CMJ, MB throw, agility test	Serve ↑ – Power ↑ – Agility ↑
24	Choudhary et al. [18]	HIIT	8 wks	36 (15–19 y)	5–10 m sprint, T-test, CMJ, SJ, DJ	Speed ↑ – Agility ↑ – Power ↑
25	Fernández-Fernández et al. [34]	Drills + HIIT vs drills	8 wks	20 (~15 y)	Yo-Yo, 505 test, sprint, CMJ	Endurance ↑ – Agility ↑

Note. Legends: "↑" = significant improvement or increase; "↓" = significant decrease in time (performance gain). Performance parameters: Speed (sprint or acceleration), Agility (change of direction, footwork), Power (jumping, strength, explosive output), Power-Upper (upper-body power, e.g., throws), Accuracy (precision), Endurance (aerobic capacity), Skill (tennis-specific skill performance). Each study's improvements are reported for the intervention compared with the control condition or baseline, with no change indicated where applicable.

patterns of responsiveness across developmental stages and training approaches.

Where reported, competitive level (novice, trained, or elite junior) and maturation status (prepubertal, pubertal, adolescent) were described using age groupings and study population characteristics; however, detailed baseline training history was inconsistently reported across studies. Upper-body power (serve velocity) and balance showed consistent gains, whereas accuracy outcomes were less consistent. Collectively, the evidence indicates that diverse training modalities can positively influence multiple performance domains in youth tennis.

Table 4 summarizes the domain-specific risk of bias assessment for all included studies. Randomized controlled trials were evaluated using the Revised Cochrane Risk of Bias tool (RoB 2.0), while non-randomized and quasi-experimental studies were assessed using ROBINS-I.

The assessment covers key domains, including the randomization process, deviations from intended interventions, missing outcome data, and measurement of outcomes. Overall risk of bias judgments were derived by considering all domains collectively. Most randomized trials demonstrated low risk of bias or some concerns, whereas non-randomized studies showed moderate risk. This was primarily due to limitations in allocation procedures and intervention deviations.

In Table 5, sprint performance (5–20 m) improved across various interventions, such as plyometric training, high-intensity interval training (HIIT), core training, and resisted sprint training. Functional and neuromuscular training also enhanced short-distance acceleration, particularly in younger players.

While nearly all programs showed gains, effect sizes varied, with plyometric training and high-intensity interval training (HIIT) producing the

Table 4. Risk of Bias/Quality Assessment of Included Studies

Study (Authors, Year)	Randomization Process	Deviations from Intended Interventions	Missing Outcome Data	Measurement of the Outcome	Overall Risk of Bias
Behringer et al. [11]	Some concerns	Low	Low	Low	Some concerns
Fernández-Fernández & Ellenbecker [28]	Some concerns	Low	Low	Low	Some concerns
Fernández-Fernández et al. [33]	Low	Low	Low	Low	Low
Fernández-Fernández et al. [13]	Low	Low	Low	Low	Low
Kilit & Arslan [19]	Some concerns	Low	Low	Low	Some concerns
Yildiz et al. [22]	Low	Low	Low	Low	Low
Zirhli & Demirci [23]	Moderate	Moderate	Low	Low	Moderate
Arslan & Ergin [16]	Some concerns	Low	Low	Low	Some concerns
Sannicandro et al. [32]	Moderate	Moderate	Low	Low	Moderate
Ziagkas et al. [37]	Serious	Moderate	Moderate	Low	Serious
Sinković et al. [14]	Low	Low	Low	Low	Low
Novak et al. [25]	Low	Low	Low	Low	Low
Canós et al. [24]	Low	Low	Low	Low	Low
Bashir et al. [36]	Some concerns	Low	Low	Low	Some concerns
Bangari et al. [41]	Moderate	Moderate	Low	Low	Moderate
Ergin & Arslan [42]	Moderate	Moderate	Low	Low	Moderate
Wang et al. [40]	Low	Low	Low	Low	Low
Kocyigit et al. [38]	Moderate	Moderate	Low	Low	Moderate
Terraza-Rebollo et al. [35]	Moderate	Moderate	Low	Low	Moderate
Shi et al. [43]	Some concerns	Low	Low	Low	Some concerns
Moya-Ramón et al. [39]	Low	Low	Low	Low	Low
Chen [15]	Moderate	Moderate	Low	Low	Moderate
Kızılca & Okut [17]	Some concerns	Low	Low	Low	Some concerns
Choudhary et al. [18]	Low	Low	Low	Low	Low
Fernández-Fernández et al. [34]	Some concerns	Low	Low	Low	Some concerns

Note. Risk of bias was assessed using the Revised Cochrane Risk of Bias tool (RoB 2.0) for randomized controlled trials and ROBINS-I for non-randomized studies. Domains were rated as “Low,” “Some concerns,” “Moderate,” or “Serious,” and an overall judgment was derived accordingly.

Table 5. Training Effects on Speed (Sprint Performance)

Study	Training Type	Sprint Test (Distance)	Pre vs Post Results	Significance	Outcome on Speed
Fernández-Fernández [33]	Combined repeated-sprint + strength vs control	20 m sprint (with 5 m splits)	EG: 5 m: 1.15 → 1.10 s; 20 m: 3.30 → 3.20 s; CG: no change	$p < 0.05$ (EG vs CG)	Improved sprint speed (all split times significantly faster in training group)
Fernández-Fernández [13]	Plyometric training vs control	5 m, 10 m, 20 m sprint	TG: ~3–5% faster; CG: no change	$p < 0.01$ (TG vs CG)	Improved sprint times (significant decreases at 5, 10, and 20 m in plyometric group)
Fernández-Fernández [34]	Tennis drills + HIIT vs drills only	20 m sprint (5 m split)	Both groups: ~0–1% change (n.s.)	n.s. (no significant change)	No improvement in 5 m or 20 m sprint speed in either group
Yildiz et al. [22]	Functional training vs traditional vs control	10 m sprint (acceleration)	FT: 2.25 → 2.10 s; TT: 2.28 → 2.27 s; CG: no change	$p < 0.001$ (FT vs TT/CG)	Improved acceleration in the functional group (FT); no change in traditional training (TT)

Table 4. Continued.

Study	**Training Type**	**Sprint Test (Distance)**	**Pre vs Post Results**	**Significance**	**Outcome on Speed**
Kilit & Arslan [19]	HIIT vs on-court tennis training	20 m sprint	HIIT: ~3% faster; OTT: ~2% faster	$p > 0.05$ (group difference); both improved	Improved sprint speed in both groups (no significant difference between HIIT and standard training)
Moya-Ramón et al. [39]	Resisted sprint vs unresisted sprint	5 m, 10 m, 20 m sprint	Both groups: 5 m and 20 m times ↓ ~1–4%	$p < 0.05$ (pre vs post, both)	Improved acceleration and sprint speed in both groups (no between-group difference, except slightly greater 5 m gain in resisted sprint training)
Canós et al. [24]	Flywheel vs machine strength vs control	5 m, 10 m, 15 m sprint	FG: 5 m 1.20 → 1.14 s; MG: 1.21 → 1.14 s; CG: ~1.20 s (no change)	$p < 0.01$ (FG and MG vs CG)	Improved 5–15 m sprint in both flywheel and machine groups; no change in control
Wang et al. [40]	Neuromuscular training vs control	10 m sprint	NMT: 2.10 → 1.98 s; Control: 2.11 → 2.09 s	$p < 0.05$ (group × time)	Improved sprint speed in the NMT group (significantly faster 10 m time vs control)
Sinković et al. [14]	Plyometric (jump and COD drills) vs control	20 m sprint (COD included)	Plyometric group: 20 m time ↓ (exact values not reported); Control: no change	$p < 0.05$ (post-test)	Improved sprint and COD speed in the plyometric group
Kızılca & Okut [17]	Core training	20 m sprint	Core training group improved significantly; control group no change	$p < 0.05$	Improved sprint performance in the core training group
Novak et al. [25]	Flywheel plyometric vs machine vs control	5 m, 10 m sprint	Week 4: both FG and MG ~5% faster at 5–10 m; Control: no change	$p < 0.001$ (FG/MG vs control)	Improved acceleration (5 m, 10 m) in both training groups; no improvement in control
Choudhary et al. [18]	HIIT vs control	5 m, 10 m sprint	HIIT group: 5 m improved by −2.7%; 10 m improved by −6.5%; Control: no meaningful change	$p < 0.001$ (group × time interaction)	Significant speed gains in the HIIT group; no improvement in control

Abbreviations: EG = experimental group; CG = control group; TG = training group; FT = functional training; TT = traditional training; HIIT = high-intensity interval training; OTT = on-court tennis training; RST = resisted sprint training; FG = flywheel (isoinertial) group; MG = machine-based group; NMT = neuromuscular training. "↑" denotes faster times (performance improvement); n.s. = not significant.

most robust improvements. The evidence supports sprint speed as one of the most trainable capacities in youth tennis players.

In Table 6, agility and change-of-direction (COD) performance improved significantly across nearly all interventions. Plyometric training, high-intensity interval training (HIIT), functional drills, and core stability training consistently reduced agility test times. Flywheel and neuromuscular training also demonstrated large improvements. Collectively, the findings presented in Table 6 highlight agility as a particularly responsive domain, with multidimensional interventions (plyometric plus core training, HIIT plus drills) showing superior benefits.

Power outcomes varied depending on the intervention type (Table 7). Plyometric and high-intensity interval training (HIIT) programs significantly improved jump performance, while core and flywheel training enhanced upper-body power, including medicine-ball throws and serve velocity. Some interventions, such as integrated core–plyometric training, showed limited effects on vertical jump, underscoring the need for a targeted stimulus. Overall, power gains were evident but training-specific, suggesting that different approaches are required for lower- and upper-body development.

Table 6. Training Effects on Agility (Change-of-Direction Speed)

Study	Training Type	Agility Test	Pre vs Post Results	Significance	Outcome on Agility
Fernández-Fernández [13]	Plyometric vs control	Modified 505 COD test	TG: 505 time 2.45 → 2.30 s; CG: 2.44 → 2.43 s	$p < 0.01$ (TG vs CG)	Improved COD speed in the plyometric group (significantly faster 505 time)
Fernández-Fernández [34]	Drills + HIIT vs drills only	505 COD test	HIIT + drills: 505 time 2.37 → 2.25 s; drills: 2.36 → 2.34 s	$p < 0.05$ (HIIT group only)	Improved agility in the combined HIIT group; no change in drills-only group
Yildiz et al. [22]	Functional vs traditional vs control	T-test (shuttle agility)	FT: 12.1 → 10.9 s; TT: 12.0 → 11.8 s; CG: ~12.0 s (no change)	$p < 0.001$ (FT vs others)	Improved agility in the functional group; minimal or no change in traditional training
Bashir et al. [36]	Core stability vs control	505 COD test	Core TG: 505 time 2.52 → 2.37 s; control: 2.50 → 2.49 s	$p = 0.001$ (group × time)	Improved agility in the core training group (significantly faster 505 time vs control)
Ziagkas et al. [37]	Plyometric vs baseline	Tennis agility circuit	Plyometric group: agility time ↓ (~8%)	Reported improvement	Improved tennis-specific agility after plyometric training
Kilit & Arslan [19]	HIIT vs tennis training	T-drill agility	HIIT: 9.5 → 8.9 s; OTT: 9.6 → 9.3 s	$p < 0.05$ (HIIT pre vs post)	Improved agility in both groups; slightly greater gain in the HIIT group
Moya-Ramón et al. [39]	Resisted vs unresisted sprint	COD 90° pivot test	Both groups: COD time ↓ ~2–3%	$p < 0.05$ (pre vs post)	Improved COD ability in both groups; no between-group difference
Arslan & Ergin [16]	Core strength vs control	Shuttle agility (4 × 10 m)	Core TG: shuttle time ↓ ~6%; control: no change	$p < 0.01$ (TG vs CG)	Improved shuttle agility in the core-trained group
Canós et al. [24]	Flywheel vs machine vs control	COD 180° test (both sides)	FG: ~5% faster; MG: ~6% faster; CG: ~0%	$p < 0.01$ (FG and MG vs CG)	Improved COD agility in both flywheel and machine groups; no change in control
Wang et al. [40]	Neuromuscular vs control	505 COD test (children)	NMT: 505 time 2.80 → 2.65 s; control: ~2.78 s (no change)	$p < 0.05$ (group × time)	Improved COD agility in the NMT group
Sinković et al. [14]	Plyometric vs control	Reactive agility drill	Plyometric group: reactive agility time ↓; control: no change	$p < 0.01$ (between groups)	Improved reactive agility in the plyometric group
Novak et al. [25]	Flywheel vs machine vs control	T-test and 505 COD tests	FG and MG: T-test ↓ ~4–5%; control: no change	$p < 0.001$ (FG/MG vs CG)	Improved agility in both training groups
Bangari et al. [41]	Core + plyometric	Pro-agility shuttle	Experimental group: times improved; control: no change	$p = 0.015$ (group × time)	Significant improvement in agility for the training group
Choudhary et al. [18]	HIIT vs control	Modified T-test	Experimental group: ~8% faster post-test; control: negligible change	$p < 0.001$	Significant improvement in agility performance in the HIIT group
Kızılca & Okut [17]	Core training	Illinois agility test	Training group improved significantly	$p < 0.05$	Improved agility in the core training group

Note: All training interventions that significantly improved agility (lower times in agility tests) are bolded as improved. “No change” indicates that agility was not significantly affected.

Table 7. Training Effects on Power (Muscular Strength/Power Outcomes)

Study	Training Type	Power Outcome Measures	Pre vs Post Results	Significance	Outcome on Power
Behringer et al. [11]	Plyometric vs machine RT	Tennis serve velocity (power)	Plyometric: +3.8% ↑ in serve speed; Machine: +1.2% (n.s.)	$p < 0.05$ (plyometric vs control)	Improved upper-body power (serve velocity) with plyometrics; no significant gain with machine RT
Fernández-Fernández [33]	Repeated-sprint + strength	CMJ height; RSA fatigue index	CMJ: 31 → 34 cm; RSA fatigue: ~−1% (n.s.)	$p \leq 0.05$ (CMJ)	Improved lower-body power (jump height ↑); RSA fatigue unchanged
Fernández-Fernández [13]	Plyometric vs control	CMJ; standing long jump; OMB throw; serve speed	All ↑ in TG (e.g., CMJ +10%, SLJ +7%, OMB +8%); no change in CG	$p < 0.01$ (all metrics)	Improved explosive power across all measures with plyometric training
Yildiz et al. [22]	Functional vs traditional vs control	Vertical jump (cm)	FT: 25 → 28 cm; TT: 24 → 25 cm; CG: ~24 cm	$p < 0.001$ (FT vs TT/CG)	Improved jump power in the functional group; minimal change in traditional training
Bashir et al. [36]	Core stability vs control	Dynamic balance; core strength	Training: balance reach +12%; MB throw +8%	$p < 0.01$ vs control	Improved functional power (core strength and balance) in the core group
Moya-Ramón et al. [39]	Resisted vs unresisted sprints	CMJ; standing long jump	Both groups: CMJ +5–6%; SLJ +4–5%	$p < 0.05$ (pre vs post)	Improved leg power in both groups; no clear between-group difference
Kızılca & Okut [17]	Core training	Serve speed; CMJ; MB throw	Serve speed ↑; CMJ ↑; MB throw ↑	$p < 0.05$	Improved serve power, jump power, and throwing performance
Arslan & Ergin [16]	Core strength vs control	Standing long jump; MB throw	Core TG: SLJ +9 cm; MB throw +10%; control: no change	$p < 0.01$ (TG vs CG)	Improved explosive strength of lower and upper body in the core-trained group
Canós et al. [24]	Flywheel vs machine vs control	CMJ; MB throws (overhead, FH, BH)	CMJ: ~+11% (FG and MG); MB throws: FG +6–9%, MG +3–4%; control: ~0%	$p < 0.001$ (FG/MG vs CG)	Improved lower-body power in both groups; greater upper-body power gains with flywheel training
Sinković et al. [14]	Plyometric vs control	CMJ; reactive jump test	Plyometric: CMJ +3.5 cm; reactive strength index ↑; control: no change	$p < 0.05$ (vs control)	Improved explosive power and stretch–shortening cycle performance
Novak et al. [25]	Flywheel vs machine vs control	CMJ; MB throws; serve speed	CMJ: FG +10%, MG +11% (both ↑); MB: FG +8% (↑), MG +2% (n.s.); Serve: MG +5.8% (↑), FG +2% (n.s.)	$p < 0.01$ vs control	Improved jump power in both groups; modality-specific upper-body power gains
Bangari et al. [41]	Core + plyometric	Vertical jump (SJ, CMJ)	Experimental: no meaningful change; control: no change	n.s.	No significant improvement in jump power
Choudhary et al. [18]	HIIT vs control	CMJ, SJ, DJ jump heights	Experimental: CMJ +15.4%, SJ +10.8%, DJ +12.4%; control: negligible change	$p < 0.001$	Significant increases in explosive leg power with HIIT

Key: CMJ = countermovement jump; OMB = overhead medicine ball; MB = medicine ball; FH/BH = forehand/backhand; RSA = repeated sprint ability. *Improved* indicates significant gains in power or strength outcomes; "n.s." = not significant. Many interventions yielded moderate-to-large effect size improvements in jump and throw tests, reflecting enhanced muscular power.

In Table 8, endurance adaptations were most prominent in high-intensity interval training (HIIT), repeated-sprint, and neuromuscular interventions. Improvements were recorded in Yo-Yo IR tests, shuttle runs, and VO_2max outcomes, often surpassing the effects of standard tennis training. While resistance- and flywheel-based programs contributed to moderate endurance gains, HIIT provided the most consistent and substantial improvements. This reinforces HIIT as a superior method for enhancing aerobic and anaerobic capacity in adolescent players.

In Table 9, balance outcomes were positively influenced by core, plyometric, and flywheel-based programs. Dynamic balance measures (e.g., Y-Balance, SEBT) consistently improved, with dynamic core training showing greater effects than static protocols.

Plyometric and HIIT interventions also enhanced reactive or postural stability. Collectively, these findings suggest that incorporating balance-specific drills or integrated core/plyo elements can meaningfully improve stability, an essential quality for performance and injury prevention in youth tennis.

Based on the findings of this scoping review, the evidence demonstrates that a variety of structured training interventions are effective in improving at least one of the five targeted performance domains among youth tennis players. Plyometric training, functional training, resisted sprint training, HIIT, and neuromuscular training consistently enhanced linear sprint and acceleration times. In contrast, core stability, functional training, plyometric drills, HIIT, and flywheel strength training proved effective for improving change-of-direction ability. Explosive power measures, including CMJ, SJ, DJ, medicine-ball throws, and serve velocity, showed notable gains following plyometric programs, core training, isoinertial/flywheel strength training, and HIIT. Although evidence on accuracy was relatively limited, improvements were observed in serve velocity and stroke precision, particularly after plyometric, core, and resistance-based interventions. Finally, endurance outcomes such as VO_2max and Yo-Yo test performance improved significantly with HIIT, resisted sprinting, and tennis-specific conditioning, with HIIT demonstrating the strongest and most consistent effects.

Discussion

This scoping review synthesized evidence from 25 intervention studies published between 2015 and 2025 that examined the effects of structured training programmes on physical performance outcomes in youth tennis players ($\leqslant$19 years). Overall, the findings indicate that a wide range of conditioning modalities can elicit meaningful performance adaptations in developing players. However, the magnitude and specificity of these effects vary according to training

Table 8. Training Effects on Endurance (Aerobic / Anaerobic Capacity)

Study	Training Type	Endurance Test	Pre vs Post Results	Significance	Outcome on Endurance
Fernández-Fernández [33]	Repeated-sprint + strength vs control	Yo-Yo Intermittent Recovery Test	EG: distance ↑ ~8%; CG: no change	$p < 0.05$ (EG vs CG)	Improved aerobic endurance in the training group
Fernández-Fernández [34]	Tennis drills + HIIT vs drills only	Yo-Yo IR1 test	HIIT + drills: ↑ ~10%; drills: ~no change	$p < 0.01$ (HIIT vs drills)	Enhanced intermittent endurance in the HIIT group
Kilit & Arslan [19]	HIIT vs on-court tennis training	20 m shuttle run	HIIT: ↑ ~12%; OTT: ↑ ~6%	$p < 0.05$ (group difference)	Both groups improved, with greater endurance gains in HIIT
Moya-Ramón et al. [39]	Resisted vs unresisted sprint	Yo-Yo IR test	Both groups ↑ ~5–7%	$p < 0.05$	Endurance improved in both training groups
Canós et al. [24]	Flywheel vs machine vs control	Yo-Yo IR2 test	FG and MG ↑ ~9–11%; CG stable	$p < 0.001$ (FG/MG vs CG)	Significant endurance improvement in both training groups
Wang et al. [40]	Neuromuscular training vs control	Shuttle run	NMT ↑ ~6%; control unchanged	$p < 0.05$	Improved aerobic capacity in the NMT group
Novak et al. [25]	Flywheel vs machine vs control	Yo-Yo IR1 test	FG and MG ↑ ~10–12%; control stable	$p < 0.001$	Endurance significantly improved in both training groups
Choudhary et al. [18]	HIIT vs control	VO_2max (20 m shuttle run)	HIIT ↑ +5.7%; control stable	$p < 0.001$ (group × time)	Significant increase in VO_2max in the HIIT group

Table 9. Training Effects on Balance (Static / Dynamic Stability)

Study	Training Type	Balance Test	Pre vs Post Results	Significance	Outcome on Balance
Bashir et al. [36]	Core stability vs control	Dynamic balance reach test	TG: ↑ ~12%; control: no change	$p < 0.01$	Improved dynamic balance in the core training group
Arslan & Ergin [16]	Core strength vs control	Balance reach and shuttle test	TG: ↑ ~6–7%	$p < 0.01$	Improved balance and stability in the core-trained group
Canós et al. [24]	Flywheel vs machine vs control	Star Excursion Balance Test (SEBT)	FG and MG: ↑ ~10%; CG unchanged	$p < 0.01$	Significant balance improvement in both strength training groups
Sinković et al. [14]	Plyometric vs control	Reactive balance and jump test	Plyometric group: ↑ stability under perturbation; control: no change	$p < 0.05$	Improved reactive balance in the plyometric group
Novak et al. [25]	Flywheel vs machine vs control	Dynamic balance (SEBT)	FG: ↑ ~8%; MG: ↑ ~6%; CG: no change	$p < 0.001$	Both training groups improved dynamic balance
Bangari et al. [41]	Core plus plyometric vs control	Balance platform test	Training group improved stability; control: no change	$p < 0.05$	Significant balance gains in the combined training group
Choudhary et al. [18]	HIIT vs control	Biodex Balance System	HIIT: balance indices improved; control: unchanged	$p < 0.001$	HIIT enhanced postural balance
Shi et al. [43]	Rope jumping training	Dynamic balance and hitting stability tests	Rope jumping: ↑ dynamic balance and hitting stability; control: no change	$p < 0.05$	Significant improvements in balance and stroke stability

type, duration, and developmental stage. Across the included literature, the most consistent and robust improvements were observed in speed, agility, and power. These outcomes were particularly evident following plyometric training, high-intensity interval training (HIIT), functional training, and neuromuscular-based interventions.

In contrast, performance domains such as accuracy and endurance were less frequently assessed and demonstrated more variable responsiveness. This highlights important gaps in the current evidence base. Collectively, the findings suggest that youth tennis performance is highly adaptable to structured, sport-specific conditioning. At the same time, the effectiveness of training interventions appears to be domain-dependent and influenced by methodological and developmental factors. A key novel contribution of this review is the identification of accuracy and balance as systematically under-researched yet performance-critical domains in youth tennis. The limited and heterogeneous evidence in these areas highlights an important research gap and supports the need for integrated intervention models that combine physical, technical, and perceptual training components.

Linear sprint speed (5–20 m) was assessed in 12 studies. Plyometric training consistently improved acceleration performance, with Fernández-Fernández et al. [13] reporting 3–5% decreases in sprint times. Similar improvements were confirmed in later trials [14, 25]. Functional training interventions demonstrated particularly strong gains in 10 m sprint times among prepubertal athletes [22]. HIIT interventions also enhanced sprint ability, with Choudhary et al. [18] observing significant reductions of 2.7% at 5 m and 6.5% at 10 m. Flywheel and machine-based strength programs produced comparable short-sprint improvements [24]. These convergent findings indicate that explosive, neuromuscularly demanding programs are effective in accelerating youth players' speed capacities, regardless of modality. However, heterogeneity in sprint test distances and testing protocols complicates precise comparisons.

Agility, particularly change-of-direction (COD) performance, was one of the most frequently assessed domains. Plyometric training interventions consistently improved 505 agility, Illinois tests, and reactive agility drills [13, 14]. Core training demonstrated notable benefits, with Bashir et al. [36] and Arslan and Ergin [16] reporting significant improvements in shuttle and 505 tests. These effects were attributed to enhanced trunk stability. Functional training was superior to traditional conditioning for agility development in children [22, 23]. Neuromuscular training also yielded broad COD improvements among preadolescents [40]. Across modalities, agility gains were robust and consistent, suggesting that this domain is particularly responsive to structured youth interventions.

Power was assessed using jump tests, medicine-ball throws, and serve velocity. Plyometric training enhanced countermovement jump (CMJ), squat jump (SJ), and standing long jump performance across multiple studies [13, 25]. However, not all interventions produced uniform gains. Bangari et al. [41] reported no significant jump improvements following core–plyometric integration. HIIT was effective, with Choudhary et al. [18] demonstrating approximately 10–15% gains in CMJ, SJ, and drop jump (DJ). Upper-body power outcomes were more variable. Dynamic core programs enhanced medicine-ball throw performance more than static programs [17], and flywheel resistance training produced larger throwing gains than traditional machine-based training [24]. Serve velocity improved in several interventions, particularly those incorporating explosive or core strength elements [11, 15]. Overall, power adaptations appear to be training-specific. Plyometric and HIIT interventions primarily enhanced lower-body explosiveness, whereas core and resistance-based modalities preferentially improved upper-body and serve-related power.

Serve and stroke accuracy were assessed less frequently and yielded inconsistent results. Early evidence from Fernández-Fernández et al. [28] and Behringer et al. [11] suggested minimal accuracy gains despite improvements in serve velocity. More recent studies similarly showed limited effects of physical training on accuracy, with skill-based improvements being secondary or negligible [24, 25]. This indicates that technical coaching, rather than conditioning alone, may be the primary driver of accuracy.

Beyond youth populations, emerging evidence in slightly older tennis athletes further supports the utility of integrative conditioning approaches. For example, Choudhary et al. [44] reported that a 12-week combined yoga and elastic-band resistance training program significantly improved muscular endurance, flexibility, and dynamic mobility in intermediate-level male tennis players. Large effect sizes were observed for upper-body endurance and agility-related outcomes. Future interventions should explore integrated models combining physical and perceptual training to enhance precision.

Endurance outcomes were heterogeneous across studies. HIIT demonstrated the clearest benefits, with VO_2max and shuttle test improvements reported by [19, 44]. Repeated-sprint plus strength programs modestly improved aerobic capacity, as reported by Fernández-Fernández et al. [33]. Resisted sprint and flywheel programs produced small gains in intermittent endurance [25, 39]. Neuromuscular training improved aerobic capacity in preadolescents [40]. Taken together, endurance gains appear most consistent in HIIT and neuromuscular interventions, whereas strength-dominant programs yielded smaller improvements.

Several methodological limitations temper interpretation. First, sample sizes were modest in most trials (n = 16–36), raising concerns about statistical power. Second, while randomized controlled trials (RCTs) were common, quasi-experimental and pre–post designs also contributed, potentially inflating the risk of bias [30]. Third, intervention durations ranged from 6–12 weeks, which limits understanding of long-term adaptations. Additionally, reporting quality was inconsistent. Only a subset of studies adhered to exercise reporting standards such as CERT [45]. Outcome measures also varied widely, complicating cross-study synthesis (e.g., different sprint distances and agility test types).

A comprehensive approach to training includes optimizing physical, technical, and tactical preparation. Methods such as circuit training, fitness training, and the use of modern technical tools are recommended to improve specific motor skills and to provide feedback during training [46]. The intensity, frequency, and duration of training significantly affect the psychological and physical responses of young athletes. High-intensity training can lead to increased stress and elevated biochemical markers of muscle damage. This indicates the need for careful monitoring of training loads [47].

Plyometric training is frequently used to enhance performance in young tennis players. It is characterized by exercises involving explosive movements that improve power and agility. This type of training is short, inexpensive, and easy to implement, which makes it accessible for many coaches [48].

Recent evidence highlights additional training modalities that complement established interventions in youth tennis. Shi et al. [43] demonstrated that a six-week rope-jumping program significantly improved dynamic balance and hitting stability. This finding underlines the importance of coordination-based conditioning. In the collegiate setting, Wakeham and Jacobs [49] reported that structured preseason strength and conditioning enhanced physical preparedness. Their findings showed reductions in injury risk and improvements in explosive strength and agility, providing translational insights for advanced junior players. At the elite level, Reid, Morgan, and Whiteside [50] documented the high-intensity demands of Grand Slam match play. These demands were characterized by repeated bursts of speed, rapid directional changes, and the need for sustained power output. This reinforces the necessity of multi-component training in developing athletes. Collectively, these studies support the view that targeted conditioning programs enhance balance, power, and agility. They also align with the physiological and tactical demands of competitive tennis.

Practical Methods and Means for Developing Key Performance Domains in Youth Tennis Players

The synthesis of 25 intervention studies provides evidence on the effective methods and training means for developing the five core performance domains: speed, agility, power, accuracy, and endurance in youth tennis players. Translating these findings into practice requires identifying specific, evidence-supported approaches that can be implemented by coaches in both on-court and off-court settings.

Speed Development

Speed improvement in youth tennis is best achieved through short-distance acceleration drills, resisted sprinting, and plyometric-based explosive movements. Studies by Fernández-Fernández et al. [13, 33], Moya-Ramón et al. [39], and Novak et al. [25] demonstrated that incorporating 5–20 m sprint intervals with minimal recovery (10–20 seconds) significantly enhances linear sprint performance. In addition, resisted sprinting using sleds, elastic bands, or parachutes improved acceleration and ground reaction force generation, particularly in adolescent male players [39]. Combining tennis-specific movement drills with short sprints (e.g., side shuffles and split-step accelerations) helps bridge the gap between conditioning and skill execution.

Agility and Change-of-Direction (COD) Training

Agility, which integrates perceptual and reactive components, can be developed through multidirectional movement patterns, reaction-based COD drills, and ladder or cone agility sequences. Research by Yildiz et al. [22], Bashir et al. [36], and Sinković et al. [14] confirmed that the T-test, Illinois agility drills, and 505 COD tests can be effectively trained using short explosive shuttle runs and deceleration-focused drills. Introducing reactive agility drills, in which players respond to visual or auditory cues, further enhances game-specific responsiveness. Coaches are encouraged to integrate shadow movement sequences and split-step recovery drills to mirror real rally dynamics.

Power Development

Power improvements in both upper and lower limbs are best achieved through plyometric training, medicine-ball throws, and isoinertial resistance exercises. Plyometric programs involving countermovement jumps (CMJ), squat jumps (SJ), drop jumps (DJ), and lateral bounds have shown 7–12% increases in explosive strength after 6–8 weeks [13, 25]. For upper-body power, medicine-ball rotational throws, overhead passes, and core-integrated exercises enhance serve velocity and forehand speed [11, 15, 17, 24]. The inclusion of flywheel or isoinertial training has also been found to produce substantial gains in both lower-body explosiveness and upper-body strength [24]. Coaches should progress from bilateral to unilateral jump patterns and integrate force–velocity-specific loading to individualize power development.

Accuracy and Stroke Precision

While fewer studies have focused directly on accuracy, improvements can be facilitated through target-based serving drills, repetitive stroke accuracy routines, and variable practice conditions that mimic match situations. Core stability programs that improve postural control and trunk rotation (Chen [15]; Kızılca & Okut [17]) indirectly enhance serve consistency and shot accuracy. Coaches may apply serve-velocity-plus-precision routines, in which players aim for specific target zones at increasing speeds. This approach combines power and control within the same training session.

Endurance Development

High-intensity interval training (HIIT) remains the most effective method for improving tennis-specific endurance. Studies by Kilit and Arslan [19], Fernández-Fernández et al. [34], and Choudhary et al. [18] demonstrated significant increases in VO_2max and Yo-Yo test performance following 8-week HIIT protocols. Effective formats include 4–6 bouts of 30–45 seconds of maximal on-court movement, interspersed with 15–30 seconds of active rest. Alternating short and long HIIT intervals improves both aerobic and anaerobic capacities. Coaches can incorporate rally-based interval games or court-position rotations to enhance specificity and player engagement during endurance development.

Collectively, these interventions demonstrate that youth tennis conditioning should prioritize multi-component training models combining speed, agility, power, endurance, and technical accuracy within the same mesocycle. Progressive overload, age-appropriate intensity, and adequate recovery are critical to ensuring both performance gains and injury prevention. Coaches are encouraged to adopt evidence-based periodization models. These models sequentially emphasize specific domains while maintaining technical quality throughout.

To move beyond a purely descriptive synthesis, the findings were interpreted using an integrative modality–outcome–development perspective. Across studies, simpler and highly neuromuscularly demanding interventions (e.g., plyometrics and HIIT) elicited broad multi-domain adaptations. These effects were particularly evident in mid-to-late adolescence. In contrast, more targeted or lower-complexity interventions (e.g., isolated balance or core training) produced domain-specific effects. Functional and neuromuscular training demonstrated greater relative benefits in younger or prepubertal populations, suggesting age-dependent responsiveness to training complexity. This stratified interpretation highlights that the effectiveness of conditioning modalities in youth tennis is not uniform. It depends on developmental stage, training content, and the performance domain targeted.

These findings provide practical implications for coaching practice in youth tennis. Plyometric and high-intensity interval training (HIIT) interventions can be applied to simultaneously enhance speed, agility, and power. Core and resistance-based programs may supplement upper-body performance, particularly serve velocity. Functional and neuromuscular training appear especially effective in younger cohorts, supporting multidimensional motor development. Training interventions should be individualized according to maturation status, as developmental stage influences responsiveness to training stimuli [9, 27].

Recent studies have further expanded the evidence base for neuromuscular and preparatory interventions in youth tennis. Fernández-Fernández et al. [51] reported that neuromuscular training performed on sand surfaces elicited greater improvements in sprint, jump, and agility performance compared with training on hard courts, suggesting surface-specific adaptations. In a controlled sequencing study, Fernández-Fernández et al. [52] found that combining neuromuscular training with tennis-specific drills enhanced strength, agility, and power outcomes, with sequence order influencing effectiveness. Similarly, Fernández-Fernández et al. [53] demonstrated that neuromuscular warm-ups improved short-term speed and agility performance compared with dynamic warm-ups, highlighting practical benefits for pre-training routines. At the elite level, Reid, Morgan, and Whiteside [50] emphasized that Grand Slam match play requires repeated high-intensity bursts, rapid changes of direction, and sustained endurance, underscoring the ecological relevance of these training approaches. Collectively, these findings indicate that neuromuscular training, surface manipulation, and warm-up protocols can contribute to optimizing speed, agility, and power development in youth tennis players.

Limitations and Future Directions

While the present scoping review provides a comprehensive synthesis of structured training interventions in youth tennis, several limitations should be acknowledged. First, most included studies featured small sample sizes, typically fewer than 40 participants. This limits the statistical power and generalizability of their findings. Second, the lack of long-term follow-up assessments restricts understanding of the durability of training adaptations once the intervention ceases. Future longitudinal studies should track players across an entire competitive season or developmental stage to determine the sustainability of performance gains.

Third, considerable heterogeneity was observed in both training designs and outcome assessments. This included differences in sprint test distances (5 m vs 20 m), agility test formats (505 vs T-test), and various jumping or endurance protocols. Such variability complicates direct comparison and meta-analytic pooling of effect sizes. Standardizing testing batteries across future research would enhance cross-study comparability and help establish normative benchmarks.

Finally, a limited number of studies incorporated female participants, highlighting a gender imbalance that warrants correction in future investigations. Expanding the evidence base to include more diverse populations and competitive levels will improve the external validity and practical utility of research in youth tennis conditioning.

Conclusions

This systematic scoping review synthesized evidence from 25 intervention studies published between 2015 and 2025 that examined structured training programs in youth tennis players (⩽19 years). Overall, training interventions consistently improved at least one performance domain. The most robust and reproducible gains were observed in speed, agility, and power. Plyometric training and high-intensity interval training (HIIT) emerged as the most effective multi-domain approaches. Core stability, functional training, and neuromuscular training showed particular benefits for agility, balance, and upper-body power.

In contrast, accuracy and endurance were less frequently assessed and demonstrated more variable responses. This indicates important gaps in the current evidence base. Interpretation of the findings is limited by heterogeneity in study design, sample size, intervention duration, and outcome measures. Future research should prioritize well-powered randomized controlled trials, standardized testing protocols, and longitudinal designs. Such approaches would allow examination of the sustainability and match-play transfer of training adaptations. Overall, the evidence supports the use of structured, sport-specific, and multi-component training programs to enhance physical performance and promote long-term athletic development in youth tennis players.

Conflict of Interest

The authors declare that there is no conflict of interest.

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