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Strength and Neuromuscular Training in Tennis Players: Effects on Physical and Sport-Specific Performance - A Narrative Review

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ABSTRACT

Background. Modern tennis requires repeated high-intensity efforts, including explosive acceleration, rapid changes of direction, powerful strokes, and efficient recovery between rallies. Strength and neuromuscular training are widely used to improve tennis performance, although variability in training protocols has resulted in inconsistent findings.

Aim of the study. To summarize current evidence on the effects of strength and neuromuscular training on tennis-specific performance and discuss practical implications for coaches and sports scientists.

Materials and methods. A narrative review of English-language studies indexed in PubMed and Google Scholar was conducted. Studies evaluating strength and/or neuromuscular training in tennis players of different ages and competitive levels were included. The evidence was synthesized descriptively according to intervention characteristics, performance outcomes, and practical applicability.

Results. Strength and neuromuscular training improved lower- and upper-body power, sprint ability, change-of-direction performance, vertical jump height, and serve velocity. Multicomponent programs combining resistance, plyometric, and neuromuscular exercises appear to provide broad benefits across several performance domains. However, heterogeneity in training protocols and outcome measures precluded definitive recommendations regarding optimal training strategies.

Conclusions. Strength and neuromuscular training is an essential component of long-term tennis development. Current evidence supports its role in improving key physical capacities relevant to tennis performance. Future research should focus on standardized intervention protocols, larger randomized controlled trials, and long-term follow-up to establish evidence-based training recommendations.

Keywords: tennis, strength training, neuromuscular training, athletic performance, plyometric training, physical fitness

1. INTRODUCTION

Tennis is a high-intensity intermittent sport that requires the integration of technical, tactical, and physical abilities. During match play, athletes perform repeated accelerations, decelerations, changes of direction, and explosive strokes interspersed with short recovery periods [1–3]. Consequently, physical fitness has become an important determinant of performance in modern tennis. Among the physical qualities required for successful performance, muscular strength and power play a central role. These capacities contribute to stroke production, court movement, and the ability to repeatedly perform high-intensity actions throughout a match [2–4]. Previous studies have demonstrated associations between physical fitness and tennis-specific performance, particularly serve velocity, which is considered one of the key performance indicators in competitive tennis [5,6]. To enhance these physical qualities, coaches commonly incorporate strength and conditioning programs into tennis training. Various methods have been investigated, including traditional resistance training, plyometric training, neuromuscular training, flywheel training, and isometric exercises [7–9]. Research suggests that these interventions may improve muscular strength, power, agility, sprint ability, and tennis-specific skills [7–10]. Recent systematic reviews and meta-analyses have demonstrated the effectiveness of strength and neuromuscular training in improving performance outcomes in both male and female tennis players [10–13]. However, most reviews have focused on individual training methods, selected age groups, or specific performance outcomes. Consequently, the available evidence remains fragmented, making it difficult for coaches and practitioners to identify the most effective training strategies. Furthermore, recent advances in neuromuscular, plyometric, isometric, and multimodal training approaches have generated new evidence that has not yet been comprehensively synthesized within a single review. Therefore, a broader narrative evaluation of the current literature is warranted to provide an integrated overview of the effectiveness of different strength and conditioning interventions in tennis. In addition to the development of isolated physical qualities, contemporary strength and conditioning in tennis should be considered within the broader context of the sport's technical and tactical requirements. Improvements in maximal strength or power are valuable only when athletes are able to express these capacities during rapid, coordinated, and highly specific movements. Tennis strokes require force to be generated and transferred through multiple body segments within a very short period, while court movement involves repeated transitions between acceleration, deceleration, lateral displacement, and changes of direction [2–4]. Consequently, physical preparation should aim not only to increase the absolute capacity of the neuromuscular system but also to improve the efficiency with which this capacity can be utilized during tennis-specific actions. This consideration is particularly relevant when comparing resistance, plyometric, and multimodal training approaches, as each may influence different components of performance and may therefore have a different degree of transfer to on-court tasks [7–13]. Another important aspect is the interaction between physical preparation and the substantial technical workload accumulated during regular tennis practice. Competitive players frequently combine on-court sessions, strength and conditioning, match play, and tournament participation within the same training cycle. The effectiveness of an additional conditioning stimulus may therefore depend not only on the type of exercise but also on its timing, frequency, volume, and compatibility with tennis-specific training. Excessive supplementary volume may increase fatigue and reduce the quality of technical practice, whereas appropriately selected strength and neuromuscular exercises may complement tennis training by improving physical qualities that cannot be sufficiently developed through court practice alone [4,10–13]. These considerations support an individualized approach in which conditioning methods are selected according to the athlete's performance needs, training history, age, and competitive schedule. Therefore, the aim of this narrative review was to summarize the current evidence regarding the effects of strength and neuromuscular training on tennis performance, with particular emphasis on serve velocity, muscular strength, power, agility, and sprint performance.

2. MATERIAL AND METHODS

This study was conducted as a narrative review of the literature concerning the effects of strength and neuromuscular training on tennis performance. A structured search of the scientific literature was performed using PubMed and Google Scholar databases. The search was conducted between January and July 2025 using combinations of the following keywords: "tennis", "strength training", "resistance training", "neuromuscular training", "plyometric training", "isometric training", "serve velocity", "agility", "power", "sprint performance", and "athletic performance". The inclusion criteria were: (1) original experimental studies, systematic reviews, or meta-analyses; (2) studies involving tennis players of any age, sex, or competitive level; (3) studies examining the effects of strength- and conditioning-related interventions on physical fitness or tennis-specific performance outcomes; (4) articles published primarily between 2013 and 2025 for the principal evidence synthesis, while earlier relevant publications were included to provide physiological, biomechanical, and methodological context; and (5) full-text availability. Studies were excluded if they focused primarily on injury rehabilitation, medical treatment, or non-tennis populations. Following screening of titles, abstracts, and full texts, studies most relevant to the objectives of the review were selected for the principal evidence synthesis. Additional foundational publications and recent tennis-specific studies identified through reference screening were included to provide biomechanical, physiological, and practical context. The collected evidence was analyzed descriptively and organized according to three main topics: (1) physical demands of tennis, (2) effects of strength and neuromuscular training on tennis performance, and (3) comparison of training modalities. Owing to the heterogeneity of study designs, participant characteristics, intervention protocols, and outcome measures, a quantitative synthesis was not performed. As this study was designed as a narrative review, no formal assessment of methodological quality or risk of bias was performed.

3. AIM OF THE STUDY

The aim of this study was to provide a comprehensive overview of the current evidence regarding the effects of strength and neuromuscular training on physical and tennis-specific performance. Particular attention was given to the influence of different training modalities, including resistance, plyometric, isometric, and multimodal training, on serve velocity, muscular strength and power, sprint performance, change-of-direction ability, and reactive agility. The review also aimed to compare the adaptations associated with different training approaches and to examine factors that may influence training responses, including age, biological maturation, competitive level, training dose, and the specificity of the applied exercises. An additional objective was to translate the available scientific evidence into practical considerations for the planning and individualization of strength and conditioning programs in tennis players. Finally, the review sought to identify limitations of the current literature and areas requiring further investigation to support the development of more precise and evidence-based training recommendations.

4. STATE OF KNOWLEDGE

4.1. PHYSICAL DEMANDS OF TENNIS

Tennis is a high-intensity intermittent sport characterized by repeated short-duration efforts interspersed with brief recovery periods. According to Pluim et al. [1], rally duration ranges from 5.5 to 6.4 s, with approximately four strokes per rally. Effective playing time accounts for only 18.6–20.0% of total match duration. Players frequently perform accelerations, decelerations, and rapid changes of direction, while average first-serve velocities reach 182 $km \cdot h^{-1}$ in men and 156 $km \cdot h^{-1}$ in women [1]. The intermittent structure of tennis creates a complex physiological and neuromuscular demand. Although individual rallies are usually short, players may be required to reproduce high-intensity actions over matches lasting considerably longer than the duration of effective playing time itself. This combination places particular importance on the ability to repeatedly generate force and power while maintaining movement quality throughout competition [1–3]. Unlike sports characterized predominantly by continuous locomotion, tennis requires frequent transitions between periods of relative inactivity and brief explosive actions. The capacity to rapidly activate the neuromuscular system after short recovery intervals is therefore an important component of match performance. Court coverage further increases the complexity of these demands. Tennis movement rarely consists of prolonged linear sprinting. Instead, players perform short accelerations over limited distances, rapid braking actions, lateral and diagonal movements, split-step actions, and repeated changes in direction [1–4]. These movements require not only concentric force production but also substantial eccentric capacity during deceleration. Effective braking enables the player to control body position, prepare for stroke production, and subsequently reaccelerate toward the next ball. Strength and conditioning programs should therefore develop both force production and force absorption rather than focusing exclusively on traditional measures of concentric strength. The upper body is simultaneously exposed to repeated high-velocity actions during serving and groundstrokes. The serve represents a particularly demanding movement because high racket-head velocity is generated through sequential contributions from the lower extremities, trunk, shoulder, elbow, and wrist [6]. Consequently, tennis performance cannot be attributed to the strength of a single muscle group. Efficient coordination of the kinetic chain is required to transfer force generated by the lower body toward the racket while maintaining technical control. This provides an important rationale for incorporating exercises that develop lower-body strength, trunk function, upper-body power, and intersegmental coordination within the same overall conditioning program [4,6].

4.2. EFFECTS OF STRENGTH AND NEUROMUSCULAR TRAINING ON TENNIS PERFORMANCE

Overall, the reviewed studies demonstrated beneficial effects of strength and neuromuscular training on several tennis-specific performance outcomes [7–13]. Serve velocity was the most frequently assessed outcome. Experimental studies reported improvements ranging from 3.8%

to 7.0% following plyometric and joint-specific isometric training interventions [8,9]. These findings were supported by meta-analyses showing significant positive effects of resistance training (ES = 0.53), multimodal training (ES = 0.79), and neuromuscular training (SMD = 0.72) on serve velocity [10,13]. Improvements in serve accuracy were reported only among female tennis players (ES = 1.14) [12]. Strength and conditioning interventions also improved muscular strength and power. Improvements in countermovement jump and medicine-ball throw performance were observed following machine-based and flywheel training [7], while meta-analyses confirmed significant gains in muscular strength and power after neuromuscular and physical training interventions [12,13]. Positive effects were additionally reported for agility and sprint performance, particularly following neuromuscular and plyometric training programs [7,11,13]. The magnitude of improvement should nevertheless be interpreted in relation to the initial training status of the athlete. Less experienced or younger players may demonstrate relatively rapid improvements when exposed to a structured conditioning stimulus, whereas highly trained competitors may require more specific or intensive interventions to achieve additional gains. Furthermore, improvements observed in general physical tests do not necessarily translate proportionally into tennis-specific performance. For example, an increase in maximal strength may expand the athlete's force-producing capacity, but the competitive value of this adaptation depends on whether the additional force can be expressed rapidly during strokes and court movement [4–6]. This distinction between general physical adaptation and sport-specific transfer is important when interpreting the available literature. Measures such as countermovement jump height, medicine-ball throw distance, short sprint time, and maximal strength provide useful information about physical capacity, whereas serve velocity, reactive agility, and tennis-specific movement tests more directly reflect the demands of competition [5,7–13]. An effective conditioning program should therefore aim to improve both categories of outcomes. General strength and power development can provide the physiological foundation, while high-velocity, coordinative, and tennis-specific exercises may facilitate the transfer of these adaptations to performance.

4.3. COMPARISON OF TRAINING MODALITIES

The effectiveness of training interventions varied according to the applied modality. Traditional resistance training primarily improved muscular strength [10,13], whereas plyometric training produced improvements in serve velocity, sprint performance, and power [9,11,13]. Neuromuscular training improved multiple performance variables simultaneously, including strength, power, agility, and sprint ability [7,11,13]. Joint-specific isometric training effectively increased serve velocity [8], while multimodal training programs were associated with improvements across multiple tennis-specific performance outcomes [10]. The differences between training modalities can be understood partly through the principle of training specificity. Traditional resistance exercises allow relatively high external loads to be applied and are therefore particularly useful for increasing maximal force-producing capacity. However, many competitive tennis actions occur within short time periods in which athletes cannot express maximal force slowly. Plyometric exercises provide a complementary stimulus by emphasizing rapid eccentric–concentric transitions and explosive force production. This may explain their favorable effects on sprint, power, agility, and serve-related outcomes [9,13,15]. Neuromuscular training represents a broader concept and may incorporate exercises targeting strength, balance, coordination, core stability, power, and movement control. Such programs may be particularly appropriate for tennis because performance depends on the simultaneous integration of several physical capacities rather than on a single isolated characteristic [11,13]. Current evidence indicates meaningful improvements in serve velocity, agility, sprint performance, muscular strength, and power after neuromuscular interventions, although the magnitude of benefit varies according to the selected training modality and athlete characteristics [13].

Multimodal training may provide an additional advantage from a practical perspective because different exercises can be selected to target complementary adaptations within the same training cycle. Resistance exercises can establish a foundation of strength, whereas plyometric and high-velocity movements can develop the ability to express force rapidly. Sprint and change-of-direction drills can subsequently increase the specificity of the stimulus. This does not imply that every modality must be included in every session. Rather, the relative emphasis can be modified according to the training phase, athlete profile, and competitive calendar [4,10,13].

4.4. SERVE VELOCITY AND THE KINETIC CHAIN

Serve velocity is a particularly relevant outcome because the serve is the only stroke initiated entirely by the player and provides a direct opportunity to gain an offensive advantage. Its effectiveness depends on the sequential transfer of force from the lower extremities through the pelvis and trunk to the shoulder, elbow, wrist, racket, and finally the ball. A recent review of determinants of serve velocity emphasized the contribution of leg drive, hip and trunk rotation, upper-arm motion, specific isometric strength, rate of force development, and upper-body power [14]. These observations help explain why interventions directed only at a single muscle group may have a smaller transfer to serving performance than programs that train several links of the kinetic chain. The available intervention literature also indicates that improvements in serve velocity do not necessarily occur in parallel with improvements in serve accuracy. In a meta-analysis of plyometric training, maximal serve velocity improved with a moderate effect, whereas evidence for changes in serve accuracy remained inconclusive [15]. Similarly, joint-specific isometric training increased serve velocity by approximately 7% without a corresponding improvement in accuracy [8]. This distinction is practically important: physical preparation can increase the capacity to generate racket and ball speed, but technical practice is still required to preserve placement, consistency, and tactical effectiveness at higher serving velocities. Upper-body plyometric work may provide a time-efficient stimulus. In a randomized study of male youth players, one or two weekly sessions of upper-limb plyometric training over eight weeks improved shoulder rotational strength, medicine-ball performance, and serve velocity, with no clear additional advantage of the higher weekly frequency [16]. This finding supports the use of relatively low-volume supplementary power training when tennis practice and competition already create a substantial total workload.

From a biomechanical perspective, the serve illustrates why isolated increases in muscular strength may be insufficient to optimize tennis performance. Force generated by the lower extremities must be transmitted through the pelvis and trunk before contributing to upper-limb and racket velocity. Inefficient transfer at one segment of this sequence may limit the contribution of strength developed elsewhere in the kinetic chain [6,14,24,25]. Conditioning for serving performance should therefore include not only upper-body strengthening but also lower-body force production, trunk control, rotational power, and exercises requiring coordinated force transfer. The rate at which force can be produced is also important. The time available for force generation during explosive sporting actions is considerably shorter than that required to achieve maximal force during conventional strength testing. Accordingly, athletes may benefit from combining high-load resistance work with exercises performed at higher movement velocities. Medicine-ball throws, plyometric exercises, and other ballistic movements may help bridge the gap between maximal strength and the rapid force production required during serving [4,14,28]. Importantly, serve performance should not be evaluated exclusively through ball velocity. A faster serve has limited competitive value if the increase in speed is accompanied by a substantial reduction in accuracy or consistency. The available evidence demonstrates this distinction clearly: plyometric interventions can improve maximal serve velocity, whereas evidence for corresponding improvements in serve accuracy is substantially less consistent [15]. Consequently, conditioning interventions aimed at increasing serving power should be accompanied by technical practice that enables athletes to integrate increased physical capacity without compromising placement and control.

4.5. SPRINT, CHANGE-OF-DIRECTION ABILITY AND REACTIVE AGILITY

Court movement in tennis differs from linear sprinting because most actions begin from a low or moderate initial velocity and involve very short accelerations, braking, lateral movement, and repeated directional changes. Accordingly, training adaptations should be evaluated with tests that reflect both planned change-of-direction speed and the reactive component of agility.

A randomized trial in young tennis players demonstrated that six weeks of plyometric training improved several measures of explosive power and tennis-specific motor performance, including change-of-direction and reactive-agility outcomes [17]. These results are consistent with the broader meta-analytic evidence showing positive effects of neuromuscular training on agility and sprint performance [13]. Sprint-specific conditioning can also be useful. Moya-Ramon et al. compared resisted and conventional sprint training in young elite players and found that both approaches improved short sprint, jump, change-of-direction, and repeated-sprint outcomes, with resisted sprint training producing greater improvements in 5-m sprint time and standing long-jump performance [18]. More recent work comparing sprint and change-of-direction drills performed with or without a racket suggests that both general and tennis-specific variants can be integrated into in-season conditioning [19]. From a programming perspective, these findings favor short, high-quality efforts with full technical control rather than excessive running volume that may add fatigue without reproducing the mechanical demands of match play. Acceleration and deceleration should be considered interdependent components of tennis movement. A player who accelerates rapidly but cannot efficiently reduce velocity may have difficulty establishing an appropriate position for stroke production or initiating the subsequent movement. Eccentric lower-limb strength and neuromuscular control are therefore relevant to both performance and movement efficiency. Exercises involving controlled braking, landing, lateral displacement, and rapid reacceleration may complement conventional sprint and strength training by addressing the repeated acceleration–deceleration cycle characteristic of tennis [1,4,17–19]. Reactive agility introduces an additional perceptual component. In a pre-planned change-of-direction test, the athlete knows the required movement pattern before initiating the task. During a match, however, movement is determined by information obtained from the opponent’s position, racket movement, ball trajectory, and tactical situation. The physical capacity to change direction therefore represents only one component of successful on-court agility. The positive effects of plyometric and neuromuscular training on change-of-direction performance provide an important physical foundation [13,17], but this capacity should subsequently be integrated with tennis-specific perceptual and decision-making tasks. For this reason, progression from general to more specific drills may be useful. Early conditioning phases may emphasize sprint mechanics, braking ability, strength, and pre-planned directional changes. As competition approaches, these qualities can increasingly be expressed in drills incorporating a racket, ball, external stimulus, or opponent. Research comparing movement training performed with and without a racket indicates that both approaches can contribute to physical preparation [19]. The selection of drills should therefore reflect the purpose of the session rather than an assumption that greater sport specificity is always superior.

4.6. TRAINING DOSE, AGE AND INDIVIDUALIZATION

Training response is influenced not only by the exercise modality but also by age, competitive level, training history, frequency, and the amount of concurrent tennis practice. The 2025 meta-analysis by Zhou et al. found that neuromuscular training improved serve velocity, agility, sprint performance, strength, and power, but subgroup analyses suggested that the magnitude of adaptation varied with age and program characteristics [13]. Notably, more training was not consistently associated with greater improvement. This is compatible with the upper-limb plyometric study in which one weekly session produced adaptations comparable with two sessions [16], and with earlier flywheel and machine-based work showing that the largest improvements in some outcomes occurred during the first four weeks rather than continuing linearly throughout an eight-week intervention [7]. For junior players, biological maturation should also be considered when interpreting changes in strength, power, and speed. Maturity status is associated with differences in several functional characteristics in elite youth tennis players, and tennis-specific evidence demonstrates maturation-related differences in sprint, change-of-direction, and countermovement-jump performance [20,21]. Growth- and maturation-related changes can also influence neuromuscular and muscle-tendon adaptations [22]. Consequently, observed improvements in young athletes may reflect a combination of training, maturation, neural adaptation, and technical learning. Identical programs should therefore not be applied across age groups simply because they contain exercises that are generally effective in tennis. The practical objective is to match the stimulus to the athlete while preserving sufficient time and freshness for technical and tactical practice. Individualization becomes especially important in junior tennis because chronological age does not necessarily correspond to biological maturity. Players of the same age may differ substantially in body size, strength, speed, and neuromuscular characteristics as a consequence of differences in maturation status [20–22]. These differences may affect both baseline performance and the magnitude of adaptation observed during a training intervention. Coaches should therefore avoid interpreting improvements in young players solely as a consequence of the applied program without considering concurrent growth and maturation. Training history represents another relevant factor. An athlete with limited previous resistance-training experience may obtain meaningful adaptations from relatively simple exercises and modest training volumes, whereas a highly trained player may require greater specificity or manipulation of load, velocity, and exercise selection. Progression should therefore be based on the athlete's response rather than on a predetermined assumption that continuously increasing volume will necessarily produce superior results. This is consistent with evidence indicating that higher training frequency or longer interventions do not invariably result in greater improvements across tennis performance outcomes [13,16].

The interaction between conditioning and tennis practice must also be considered when determining training dose. A player completing frequent technical sessions and matches is already exposed to repeated accelerations, decelerations, serves, and high-velocity strokes. Supplementary conditioning therefore adds to an existing workload rather than occurring in isolation. During periods of high tennis volume, relatively short sessions emphasizing quality and intensity may be sufficient to maintain or develop selected physical capacities. Conversely, preparatory periods with lower competitive demands may provide greater opportunity for strength development and higher conditioning volumes.

5. DISCUSSION

The aim of this review was to summarize the current evidence regarding the effects of strength and neuromuscular training on tennis performance. Overall, the reviewed studies demonstrated beneficial effects on several key performance variables, particularly serve velocity, muscular strength, power, agility, and sprint ability [1,7–13]. A broader systematic review and meta-analysis likewise reported beneficial effects of athletic training on multiple fitness domains and stroke velocity, while emphasizing substantial between-study heterogeneity [23]. One of the most consistent findings was the improvement in serve velocity following strength and conditioning interventions. The serve is considered a crucial determinant of tennis performance and relies on efficient force transfer through the kinetic chain [6,24,25]. The positive effects observed after plyometric, isometric, and multimodal training programs suggest that enhancing force production and neuromuscular function can contribute to improved serve performance

[8–10,13]. The reviewed evidence also highlights the importance of muscular power in tennis. Due to the explosive nature of the sport, power is essential for serving, stroke production, and court movement [1,3]. Previous studies have reported associations between physical fitness characteristics and tennis-specific performance, supporting the importance of developing strength and power in tennis players [26,27]. In this regard, plyometric training appears particularly effective because of its ability to enhance explosive force production [28]. Agility and sprint ability were also positively influenced by strength and neuromuscular training [7,11,13]. These findings are consistent with previous reports demonstrating that tennis performance depends on repeated multidirectional movements, acceleration, and change-of-direction ability, which should be systematically developed through physical conditioning [1,29]. The comparison of training modalities suggests that different approaches produce distinct adaptations. Traditional resistance training primarily improves muscular strength, whereas plyometric training appears particularly relevant for power and explosive performance [9,10,13]. Neuromuscular training appears to improve multiple physical capacities simultaneously, while multimodal programs have demonstrated benefits across several performance domains [4,10,11,13]. From a practical perspective, the findings of this review have important implications for tennis coaches and strength and conditioning specialists. Given the multifactorial nature of tennis performance, training programs should not focus exclusively on maximal strength development. Instead, integrating strength, power, speed, and neuromuscular exercises may provide broader transfer to tennis-specific actions. Multimodal training programs that combine resistance exercises, plyometric drills, sprint training, and movement-specific exercises may therefore be useful for competitive tennis players [10,13,23]. The favorable effects of plyometric training observed across several studies may be explained by adaptations within the stretch-shortening cycle and improved neuromuscular efficiency. These adaptations enhance the athlete’s ability to generate force rapidly, which is particularly important during serving, acceleration, and change-of-direction movements. Since tennis performance depends largely on explosive actions performed within very short time intervals, improvements in rate of force development may translate into enhanced on-court performance. Differences in training responses may also be influenced by age, sex, competitive level, and biological maturation. Maturity status is associated with differences in strength, speed, power, and selected agility measures in elite youth tennis players [20], and tennis-specific data demonstrate clear differences in sprint, change-of-direction, and countermovement-jump performance across maturity groups [21]. Growth and maturation also influence the neuromuscular mechanisms that underpin adaptation to resistance training [22]. Evidence in female tennis players indicates favorable responses to physical training across several performance outcomes, while emphasizing the need for better-tailored training prescriptions [12]. Future studies should therefore investigate whether optimal training prescriptions vary according to demographic, maturational, and competitive characteristics. Another important consideration is the long-term periodization of strength and conditioning programs. Many tennis training interventions are relatively short; for example, the female-player systematic review included programs lasting 6–36 weeks, while several tennis-specific trials examined interventions of approximately 6–12 weeks [8,12,16,17]. Considerably less evidence is available regarding adaptations across an entire competitive season. Future research should evaluate how different training modalities can be integrated into annual training plans while balancing performance enhancement, recovery, and injury prevention. A further issue is the principle of transfer from general physical capacity to tennis-specific performance. Increases in maximal strength are valuable because they raise the athlete's force-producing potential, but this potential must be expressed rapidly and in movement patterns that resemble the temporal and coordinative constraints of tennis. This may partly explain why multimodal and plyometric programs often demonstrate stronger effects on serve velocity and explosive court movement than isolated traditional resistance training [10,15]. Strength training should therefore be viewed as a foundation that supports, rather than replaces, high-velocity power work and sport-specific movement practice. The distinction between change-of-direction speed and reactive agility is also relevant. Pre-planned tests primarily assess the physical ability to decelerate, reposition the body, and reaccelerate, whereas match play requires these actions in response to an opponent, ball trajectory, and tactical context. The positive findings from plyometric and neuromuscular interventions [13,17] indicate that physical qualities can be improved, but coaches should combine them with perceptual and decision-making drills. This is particularly important in advanced players, for whom a small gain in a laboratory or field test may not automatically translate into a meaningful competitive advantage. Current evidence also supports a conservative approach to training volume. Tennis players accumulate substantial loads from serving, groundstrokes, repeated accelerations, and tournament schedules. Adding strength and neuromuscular work without accounting for this background load may reduce movement quality or interfere with technical sessions. The observation that once-weekly upper-limb plyometric training can improve strength, power, and serve velocity in youth players [16] is therefore practically relevant. During congested competitive periods, maintaining intensity while reducing supplementary volume may be preferable to attempting to maximize every physical quality simultaneously. Injury prevention was not the primary endpoint of this review, and the present findings should not be interpreted as evidence that a specific strength program prevents tennis injuries. Nevertheless, neuromuscular preparation may improve modifiable capacities such as balance, movement control, strength, and tolerance to rapid loading. Tennis-specific prevention programs have been developed to address the combination of repetitive upper-limb loading and multidirectional lower-limb demands [30]. Performance and prevention objectives can therefore overlap, although dedicated prospective trials are required before firm conclusions can be made about injury reduction. From a practical standpoint, a periodized program may emphasize general strength during preparatory phases, progressively increase the proportion of high-velocity and plyometric work as competition approaches, and use lower-volume maintenance sessions during the season. Sprint and change-of-direction training can be integrated in short blocks before substantial fatigue develops, while upper-body power work can be coordinated with serving volume. Testing should be limited to measures that inform decisions, such as short sprint time, a tennis-relevant change-of-direction test, countermovement jump, medicine-ball throw, and serve velocity. Repeated assessment can then be used to identify whether an athlete is responding to the intended stimulus rather than simply increasing training load. An important implication of the available evidence is that improvements in tennis performance should not be interpreted as the consequence of a single physical quality. Strength, power, acceleration, agility, and stroke velocity are interrelated but distinct characteristics. An athlete may possess high maximal strength yet have limited ability to express this force rapidly, while another player may demonstrate excellent explosive performance despite comparatively modest maximal strength. The objective of conditioning should therefore be to identify which physical characteristics currently limit the individual player and to select training methods accordingly [4,5,10,13]. The concept of diminishing returns is also relevant when interpreting training dose. Athletes with little previous exposure to structured strength or plyometric training may initially demonstrate substantial adaptation, whereas additional improvements may become progressively more difficult as training status increases. Consequently, increasing the number of conditioning sessions is not necessarily the most effective strategy. Evidence demonstrating meaningful adaptations with relatively low training frequencies highlights the importance of balancing the training stimulus with recovery and the player's existing tennis workload [13,16]. Recovery is particularly important in tennis because physical conditioning is only one component of the total training load. Technical sessions, practice matches, tournaments, travel, and repeated serving can all contribute to cumulative fatigue. When supplementary strength or plyometric work is added without considering these demands, the athlete may complete the prescribed training while experiencing a reduction in movement quality or technical performance. Therefore, the effectiveness of a conditioning program should be judged not simply by the amount of work performed but by whether the athlete can consistently execute high-quality training and maintain performance across the wider training week.

The timing of different training modalities may also influence their practical value. General resistance training may receive greater emphasis during preparatory phases when sufficient recovery time is available and immediate competitive performance is less important. As competition approaches, training may progressively shift toward maintenance of strength and a greater proportion of explosive, high-velocity, and tennis-specific work. During congested tournament periods, reducing training volume while preserving selected high-intensity stimuli may help maintain neuromuscular qualities without creating unnecessary fatigue. Such an approach is consistent with the principle that training organization should reflect both the desired adaptation and the athlete's current competitive demands [4,13]. Another consideration is the selection of performance tests used to evaluate training effectiveness. Testing batteries that are excessively extensive may increase fatigue and provide information that does not meaningfully influence training decisions. Conversely, relying on a single measure may fail to capture the multidimensional nature of tennis performance. A practical assessment strategy may therefore include a limited number of complementary measures representing explosive lower-body performance, upper-body power, acceleration, change-of-direction ability, and a tennis-specific outcome such as serve velocity [5,26,29]. Repeated use of the same standardized tests can then help determine whether the athlete is adapting in the intended direction. Interpretation of these changes should nevertheless account for measurement variability and the competitive level of the athlete. A statistically detectable improvement does not automatically represent a meaningful change in competition, particularly among advanced players in whom performance differences may be small. Coaches should therefore consider the magnitude and consistency of an observed change together with its relevance to the individual athlete's playing style and performance limitations. For example, an increase in serve velocity may be particularly valuable for a player whose game relies heavily on first-strike tennis, whereas another athlete may derive greater benefit from improved movement efficiency or repeated change-of-direction ability. The available evidence additionally supports a distinction between developing physical capacity and learning to apply that capacity. Strength and conditioning can increase the athlete's potential to produce force and power, but tennis-specific practice remains necessary to incorporate these adaptations into coordinated strokes and movement patterns. This interaction may explain why improvements in general physical measures do not always correspond directly to improvements in skill-based outcomes. The absence of a consistent improvement in serve accuracy after plyometric training, despite improvements in serve velocity, provides a useful example [15]. Physical preparation and technical training should therefore be viewed as complementary rather than competing components of player development. Finally, the heterogeneity of the available literature should remain central when translating research into practice. Studies differ in participant age, sex, competitive level, previous training experience, intervention duration, training frequency, exercise selection, and outcome assessment [10–13,23]. Consequently, average effects derived from systematic reviews should not be interpreted as a universal prescription for every tennis player. Current evidence provides a framework for selecting potentially effective training methods, but the final program should be adapted according to the athlete's needs, response to training, and position within the competitive calendar. Several limitations should be acknowledged. The available studies often involved small sample sizes and heterogeneous training protocols, making direct comparisons difficult. Furthermore, most interventions investigated short-term adaptations, and evidence regarding long-term training effects remains limited [10–13]. Overall, the available evidence indicates that strength and neuromuscular training are important components of modern tennis preparation and can contribute to improvements in both physical fitness and tennis-specific performance.

6. CONCLUSION

The available evidence suggests that strength and neuromuscular training are effective strategies for improving tennis-specific performance. Positive effects were observed on serve velocity, muscular strength, power, agility, and sprint performance. Plyometric and multimodal training interventions appear particularly promising; however, the heterogeneity of study designs, participant characteristics, and training protocols precludes definitive conclusions regarding the superiority of any single training modality. Future research should focus on long-term adaptations and the optimization of training programs across different age groups and competitive levels.

Disclosure

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