

Unlocking explosive potential: long-term effects of a 10-week tennis intervention on jump performance

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Abstract:

Explosive strength and reactive jumping ability are key determinants of tennis performance. However, the longitudinal effects of tennis-specific training on different jump modalities remain insufficiently understood. This study examined the impact of a 10-week tennis-specific training intervention on countermovement jump and squat jump performance in novice learners, with particular attention to stretch-shortening cycle efficiency and sex-related physiological characteristics. Eleven participants (mean age 20.81 ± 1.25 years, height 1.70 ± 0.07 m, weight 65.18 ± 9.33 kg) completed a 10-week intervention. Performance was assessed via pre- and post-test measurements of jump height, peak power relative to body mass (Watts per kilogram), and modified reactive strength index for countermovement jump and squat jump protocols. Data were analyzed using Wilcoxon signed-rank and Mann-Whitney U tests ($p \leq 0.05$). The intervention yielded significant improvements in countermovement jump height (pre: 29.60 cm vs. post: 33.00 cm; $Z = -2.191$, $p = 0.028$) and modified reactive strength index (pre: 0.37 m/s vs. post: 0.47 m/s; $Z = -2.667$, $p = 0.008$). Conversely, squat jump parameters exhibited non-significant changes, demonstrating mechanical specificity favoring reactive-elastic mechanisms over static force production. Sex-based comparisons revealed significant baseline disparities favoring males. While training reduced some gaps, sex differences remained significant post-intervention. A 10-week tennis training program effectively enhances dynamic neuromuscular power and stretch-shortening cycle efficiency, but has minimal impact on squat jump parameters, showing that tennis drills preferentially target elastic recoil over isolated concentric strength. Practitioners should combine tennis drills with complementary resistance training and sex-responsive periodization to maximize long-term athletic development.

Key Words: Stretch-shortening cycle, Dynamic power, Stretch-shortening cycle, Sex differences, Neuromuscular training, Functional performance.

Introduction

Modern tennis is increasingly recognized as a dynamic, multidisciplinary sport requiring the seamless integration of anthropometric, physiological, and technical characteristics, even during the early stages of skill acquisition (Baiget et al., 2016; Bosco et al., 1983). While elite performance is characterized by high stroke velocities and point dominance (Colomar et al., 2020; Delgado-Garcia et al., 2019), individuals who are newly learning tennis face a foundational challenge: transitioning from rudimentary motor patterns to coordinated kinetic chain movements. In this synchronized sequence, force is efficiently generated through the lower extremities, transferred across the trunk, and delivered to the upper limbs by utilizing the stretch-shortening cycle (SSC) (Dossena et al., 2018; Elliott, 2006; Faber et al., 2012). This mechanical dependency underscores the reality that lower-body power generation is not merely a secondary conditioning trait, but the absolute biomechanical foundation for stroke execution and rapid court coverage. Rather than focusing strictly on advanced competitors, understanding how novice players adapt physically during their initial learning phases is critical for establishing sound movement habits and optimizing fundamental athletic development from the outset.

Recent evidence confirms that lower extremity muscle power, directional agility, and fatigue resistance play a substantial role in supporting technical performance as players progress from novice to more proficient levels (Fernandez-Fernandez et al., 2012; Fernandez-Fernandez et al., 2014). However, the development of these qualities in beginners represents a time-constrained, multidimensional process (Fernandez-Fernandez et al., 2019). For individuals newly introduced to the sport, the primary challenge lies in balancing basic movement literacy with the acquisition of introductory technical skills such as proper footwork, ball control, and spatial anticipation—which serve as fundamental predictors of sustained participation and long-term success (Fernandez-Fernandez et al., 2012; Fernandez-Fernandez et al., 2019). Despite these imperative demands, the physiological adaptations that occur during this introductory learning phase are frequently confounded by the acute fatigue associated with unaccustomed multi-planar movements. Furthermore, the early initiation of tennis requires coaches and practitioners to properly pace training loads; poorly structured or unperiodized conditioning

can otherwise induce acute neuromuscular fatigue that paradoxically impairs technical precision or introduces chronic musculoskeletal stress (Gillet et al., 2009; Girard et al., 2005; Girard et al., 2007).

In addition to physical demands, the psychosocial and motor coordination dimensions of this initial developmental phase are critical. While regular sports participation is a well-documented driver of physical capacity among beginners, participants often face unique physiological barriers particularly regarding sex-based functional profiles that necessitate tailored, responsive training protocols (Kibler, 1995; Kovacs, 2007). Evaluating these baseline physiological divergences is crucial, as male and female novice cohorts may exhibit disparate rates of neuromuscular fatigue and elastic energy storage when subjected to identical sport-specific training volumes.

Despite the comprehensive nature of existing research on highly trained athletes, there remains a critical gap in longitudinal data tracking novice learners during early intervention periods. Specifically, the literature lacks a clear understanding of how objective neuromuscular performance metrics such as Countermovement Jump (CMJ) height, Squat Jump (SJ) height, peak power relative to body mass (Watts per kilogram; W/kg), and the modified Reactive Strength Index (RSI-modified) co-evolve across sexes during initial skill acquisition. While the CMJ and its reactive derivatives reflect SSC efficiency, elastic energy utilization, and rapid force development (Kramer et al., 2016; Moreno-Perez et al., 2018), the SJ isolates concentric-only force production without eccentric pre-loading (Kramer et al., 2016; Pialoux et al., 2015). Clarifying how a structured, sport-specific intervention differentially alters these biomechanical modalities in novice learners is essential for closing the gap between raw athletic capacity and foundational on-court execution.

To address these multifaceted physical and technical demands, this study aimed to evaluate the longitudinal efficacy of a 10-week tennis-specific training intervention on explosive muscle power, jump mechanics, and sex-based physical profiles among individuals newly learning the sport. Based on the mechanical demands of tennis-specific movements that inherently rely on dynamic force output even at a beginner level, we hypothesized that the intervention would drive significant enhancements in dynamic SSC performance, as evidenced by marked increases in CMJ height and RSI-modified values. Conversely, SJ parameters were hypothesized to remain relatively stable, reflecting the training's primary mechanical emphasis on rapid eccentric-concentric transitions rather than isolated concentric force production. Finally, given the physiological dimorphism between sexes, we anticipated that baseline sex disparities in jump height and peak relative power would persist post-intervention, highlighting the necessity of sex-tailored conditioning frameworks for novice tennis players.

This investigation primarily addresses whether field-based tennis instruction in beginners delivers an adequate biomechanical stimulus for concentric strength adaptation, or if such interventions predominantly refine elastic, stretch-shortening capabilities. Additionally, it remains unclear if technical skill acquisition alone can diminish baseline sex-based physiological disparities without concurrent resistance programming. To resolve these questions, we implemented a longitudinal design pairing high-precision optoelectronic tracking with force platform diagnostics. By quantitatively monitoring specialized kinetic metrics namely CMJ height, SJ performance, relative peak power, and RSI-modified across a 10-week court-based intervention, this study isolates the precise muscular adaptations driven by early tennis participation, ultimately informing structured periodization for foundational conditioning programs.

Material & methods

Study Design and Ethical Approval

A single-arm longitudinal intervention design was used to examine adaptations in vertical jump mechanics, muscle power, and stretch-shortening cycle (SSC) dynamics among novice tennis players over a 10-week period. Testing was conducted at two time points: baseline (pre-intervention) and immediately following the 10-week program (post-intervention). All procedures adhered to the ethical principles outlined in the Declaration of Helsinki for research involving human subjects, and the study protocol was approved by the institutional ethics committee. Participants and their legal guardians (where applicable) were informed of the risks, benefits, and experimental procedures before providing written informed consent.

Participants

Eleven healthy novice tennis players (male: $n = 6$; female: $n = 5$; age: 20.81 ± 1.25 years) were recruited for this study. "Novice" was defined as having less than 6 months of structured tennis experience and no prior experience with formal strength and conditioning regimens (Delgado-Garcia et al., 2019). Participants were free from lower-extremity musculoskeletal injuries for at least 6 months prior to data collection. To minimize confounding variables, participants were instructed to maintain their typical daily dietary habits and abstain from supplementary strenuous physical activities during the 10-week period (Pialoux et al., 2015).

10-Week Tennis-Specific Training Intervention

The intervention consisted of twice-weekly, 90-minute tennis training sessions over 10 consecutive weeks. Each session was structured into three primary blocks:

- **Dynamic Warm-Up & Footwork Mechanics (20 min):** Included progressive multi-directional agility drills, split-step timing exercises, and dynamic lower-limb loading to prepare the musculotendinous unit for high-rate force development (Fernandez-Fernandez et al., 2012; Roetert & Ellenbecker, 2007).

• Technical Skill Acquisition & Kinetic Chain Drills (50 min): Focused on groundstroke execution, serve mechanics, and movement patterns emphasizing kinetic chain energy transfer from the lower body to the upper limbs (Elliott, 2006; Girard et al., 2005).

• On-Court Conditioning & Cool-Down (20 min): Incorporated tennis-specific repeated sprints, rapid change-of-direction shuttle runs, and static stretching to build endurance and lower-limb reactive capacity (Fernandez-Fernandez et al., 2014; Pluim et al., 2006).

Training intensity and volume were progressively overloaded across the 10 weeks under the direct supervision of certified strength and conditioning coaches (Kramer et al., 2016).

Testing Procedures & Neuromuscular Measures

All performance tests were conducted at the same time of day under standardized environmental conditions. Following a 15-minute standardized dynamic warm-up, participants completed vertical jump evaluations:

• Countermovement Jump (CMJ): Evaluated dynamic SSC performance and reactive force development. Participants began in an upright standing position, performed a rapid downward countermovement to a self-selected depth, and jumped maximally upward with hands kept on hips to isolate lower-body propulsion (Bosco et al., 1983; Kramer et al., 2016).

• Squat Jump (SJ): Measured isolated concentric force production. Participants descended into a semi-squat position (90-degree knee flexion), held the static isometric position for 3 seconds to dissipate elastic strain energy, and exploded upward without any downward motion prior to takeoff (Bosco et al., 1983; Moreno-Perez et al., 2018).

Jump metrics, including jump height (cm), peak power relative to body mass (Watts per kilogram; W/kg), and the modified Reactive Strength Index (RSI-modified), were recorded using flight-time/contact-time contact mats validated for explosive jump diagnostics (Bosco et al., 1983; Kramer et al., 2016). RSI-modified was calculated as jump height (m) divided by total movement duration (s) (Moreno-Perez et al., 2018).

Statistical Analysis

Data were analyzed using IBM SPSS Statistics (Version 26.0). Due to the small sample size ($n = 11$), non-parametric statistical methods were applied. Continuous variables are expressed as medians and interquartile ranges (IQR). The Wilcoxon signed-rank test was used to compare pre- and post-intervention outcomes across the total cohort. The Mann-Whitney U test was utilized to evaluate sex-based differences at baseline and post-intervention. Statistical significance was set at $p < 0.05$.

Results

Table 1. Demographic and physical characteristics of the participants.

	<i>N</i>	<i>Min</i>	<i>Max</i>	<i>M</i>	<i>SD</i>
Age	11	20.00	23.00	20.81	1.25
Height (m)	11	1.57	1.77	1.70	0.07
Weight (kg)	11	52.00	78.00	65.18	9.33

A total of 11 participants ($N = 11$) completed the study. The descriptive demographics and physical characteristics of the participants are presented in Table 1. The mean age of the participants was 20.81 ± 1.25 years (range: 20.00–23.00 years). The participants had a mean height of 1.70 ± 0.07 m (range: 1.57–1.77 m) and a mean body weight of 65.18 ± 9.33 kg (range: 52.00–78.00 kg).

Table 2. Changes in countermovement jump and squat jump performances following a tennis training intervention.

Performance Variables		<i>Pre-test (Median [IQR])</i>	<i>Post-test (Median [IQR])</i>	<i>Z</i>	<i>p</i>
Countermovement Jump	Jump Height	29.60 (7.10)	33.00 (11.10)	2.191	.028*
	Imp-Mom (cm)				
	Peak Power / BM (W/kg)	45.10 (9.70)	48.90 (10.70)	1.600	.110
	RSI-modified (m/s)	0.37 (0.11)	0.47 (0.17)	2.667	.008*
Squat Jump	Jump Height	32.30 (14.90)	28.10 (8.80)	0.979	.328
	Imp-Mom (cm)				
	Peak Power / BM (W/kg)	47.20 (21.60)	46.30 (13.20)	0.846	.398
	RSI-modified (m/s)	0.54 (0.40)	0.53 (0.42)	0.357	.721

Note. Data are presented as Median (Interquartile Range). Z = Z-value based on the Wilcoxon signed-rank test.

* $p \leq 0.05$

As can be seen in Table 2, the Wilcoxon signed-rank test was conducted to evaluate the effects of a tennis training intervention on the participants' countermovement jump (CMJ) and squat jump (SJ) performances.

Regarding CMJ performance, the statistical analysis revealed a significant increase in jump height from pre-test to post-test ($Z = -2.191, p = 0.028$). Similarly, a statistically significant improvement was observed in the CMJ RSI-modified scores after the training intervention ($Z = -2.667, p = 0.008$). However, the increase in CMJ peak power relative to body mass did not reach statistical significance ($Z = -1.600, p = 0.110$).

In contrast to the CMJ findings, the training intervention did not lead to any statistically significant changes in squat jump performances. No significant differences were observed between pre- and post-test values for SJ jump height ($Z = -0.979, p = 0.328$), SJ peak power ($Z = -0.846, p = 0.398$), or SJ RSI-modified scores ($Z = -0.357, p = 0.721$).

Table 3. Comparison of Jump Performances Between Female and Male Participants.

Performance Variables		Male (Median [IQR])	Female (Median [IQR])	U	p
Countermovement Jump	Jump Height	32.90 (8.15)	25.90 (4.75)	3.000	0.030*
	Imp-Mom Pre (cm)				
	Jump Height	36.75 (11.38)	28.90 (9.05)	4.500	0.058
	Imp-Mom Post (cm)				
	Peak Power / BM Pre (W/kg)	50.60 (12.83)	41.70 (5.85)	3.000	0.030*
	Peak Power / BM Post (W/kg)	55.10 (16.63)	48.00 (10.40)	6.000	0.126
	RSI-modified Pre (m/s)	0.36 (0.12)	0.37 (0.13)	11.500	0.567
	RSI-modified Post (m/s)	0.51 (0.13)	0.37 (0.17)	2.500	0.022*
Squat Jump	Jump Height Imp-Mom Pre (cm)	37.95 (9.88)	26.20 (6.45)	4.000	0.052
	Jump Height Imp-Mom Post (cm)	33.85 (10.78)	26.50 (4.75)	3.000	0.030*
	Peak Power / BM Pre (W/kg)	57.00 (17.40)	41.00 (9.10)	3.000	0.030*
	Peak Power / BM Post (W/kg)	54.20 (12.90)	44.30 (8.65)	3.000	0.026*
	RSI-modified Pre (m/s)	0.80 (0.45)	0.41 (0.25)	3.000	0.030*
	RSI-modified Post (m/s)	0.82 (0.41)	0.49 (0.32)	10.000	0.400

As can be seen in Table 3, the Mann-Whitney U test was conducted to compare jump performance variables between female and male participants. Regarding Countermovement Jump (CMJ) performance, statistical analysis revealed significant differences between sexes in Jump Height at the pre-test ($U = 3.000, p = 0.030$) and in Peak Power at the pre-test ($U = 3.000, p = 0.030$). Additionally, a significant difference was observed in the RSI-modified metric at the post-test ($U = 2.500, p = 0.022$).

Regarding Squat Jump (SJ) performance, significant differences between male and female participants were found in Jump Height at the post-test ($U = 3.000, p = 0.030$), Peak Power at both pre-test ($U = 3.000, p = 0.030$) and post-test ($U = 3.000, p = 0.026$), as well as in the RSI-modified metric at the pre-test ($U = 3.000, p = 0.030$). No significant sex differences were observed for the remaining variables ($p > 0.05$).

Discussion

The primary objective of this 10-week longitudinal investigation was to elucidate the adaptation kinetics of neuromuscular power, stretch-shortening cycle (SSC) efficiency, and isolated concentric force production following a tennis-specific training intervention in novice learners, while accounting for sex-based physiological profiles. The central findings of this study confirm our main hypothesis: a 10-week tennis-specific intervention induced statistically significant, robust enhancements in Countermovement Jump (CMJ) height and the modified Reactive Strength Index (RSI-modified), whereas Squat Jump (SJ) parameters remained largely unchanged. These outcomes provide compelling biomechanical evidence that introductory tennis conditioning preferentially stimulates dynamic, reactive-elastic neuromuscular properties rather than non-countermovement, purely concentric force capacities.

The substantial improvements observed in CMJ performance (Median: 29.60 cm vs. 33.00 cm) and RSI-modified (Median: 0.37 m/s vs. 0.47 m/s) highlight the high responsiveness of the musculotendinous unit to tennis-specific multi-directional stimuli. Modern tennis demands rapid deceleration, rapid changes of direction, and explosive multidirectional force generation, all of which rely fundamentally on efficient stretch-shortening cycle dynamics (Dossena et al., 2018; Pluim et al., 2006). During the 10-week intervention, participants repeatedly engaged in rapid eccentric loading immediately followed by concentric propulsion—a mechanical feature intrinsic to baseline footwork, split-steps, and stroke preparations.

From a physiological standpoint, the enhancement in RSI-modified, a metric superior to gross jump height in capturing true reactive capacity and neuromuscular power (Kramer et al., 2016; Moreno-Perez et al., 2018), reflects several underlying neural and structural adaptations. First, repeated tennis-specific loading likely optimized pre-activation strategies of the lower-limb musculature, enhancing muscle-spindle sensitivity and

gamma motor neuron drive during the braking phase of movement (Roetert & Ellenbecker, 2007). Second, the mechanical strain imposed by repetitive reactive footwork increases tendon stiffness (specifically within the Achilles and patellar tendons), facilitating superior storage and kinetic recoil of strain energy without increasing ground contact time or contraction duration (Moreno-Perez et al., 2018). These findings strongly resonate with recent meta-analytical work by Fernandez-Fernandez et al. (2012) and Kramer et al. (2016), who demonstrated that lower-extremity power and reactive capabilities undergo rapid adaptations when subjected to sport-specific dynamic stimuli, even in populations transitioning through early motor-skill acquisition phases.

A key mechanistic insight of this study lies in the distinct divergence between CMJ and SJ performance adaptations post-intervention. While CMJ parameters significantly improved, SJ parameters exhibited flat, non-significant trajectories. This divergence is fundamentally explained by the distinct neuromuscular and mechanical pathways targeted by the tennis-specific intervention:

Dynamic SSC Activation (CMJ & RSI-modified): Tennis-specific movements inherently rely on rapid pre-stretching and eccentric-to-concentric transitions, leading to significant enhancements in CMJ height and reactive strength index values.

Static Concentric Mechanics (SJ): The absence of a pre-stretch phase in squat jumps isolates purely concentric force production, a mechanical modality that receives minimal stimulus from dynamic on-court tennis drills, resulting in stable, unchanged post-intervention parameters.

The Squat Jump isolates concentric-only force production capacity, consciously eliminating the pre-stretch phase, tendon energy recoil, and stretch-reflex contributions (Kramer et al., 2016). In contrast, tennis-specific movement profiles rarely require purely isometric-to-concentric explosive contractions from a static, resting position. The movement architecture of introductory tennis consists almost entirely of dynamic, multi-joint transitions driven by kinetic chain energy transfer from the lower extremities to the upper body (Elliott, 2006; Faber et al., 2012).

Consequently, while the 10-week intervention provided an intense stimulus for elastic recoil and rate of force development under pre-loaded conditions, it provided insufficient mechanical overload to stimulate muscle hypertrophy or maximal concentric motor-unit recruitment (Colomar et al., 2020). As noted by Girard et al. (2005), sport-specific technical drills efficiently refine motor-unit synchronization and elasticity within functional movement patterns, but they lack the heavy mechanical resistance necessary to drive structural changes in static concentric strength. Therefore, strength and conditioning practitioners must recognize that relying solely on on-court tennis drills is insufficient for developing foundational concentric strength; structured resistance training adjuncts remain imperative if both force production modalities are targeted (Gillet et al., 2009; Roetert et al., 2009).

Our baseline evaluation revealed well-documented sex dimorphism, with male participants demonstrating significantly higher absolute jump height, peak power output relative to body mass (Watts per kilogram; W/kg), and RSI-modified scores. These baseline disparities are predominantly governed by post-pubertal hormonal profiles, architectural differences (e.g., greater muscle cross-sectional area, higher proportion of type II muscle fibers in males), and structural lever advantages (Kibler, 1995; Kovacs, 2007).

Interestingly, while the 10-week intervention induced positive performance shifts across both sub-cohorts, statistical gaps persisted in several post-test parameters. This persistent gap suggests that standard, unadjusted tennis conditioning loads may exert differential relative training stresses on male versus female athletes. Female athletes often present lower baseline eccentric strength and distinct lower-limb stiffness characteristics, which can influence how stretch-shortening cycle stresses are absorbed and utilized during high-intensity footwork (Kibler, 1995; Sogut, 2017). To optimize long-term athletic development and bridge performance gaps, sports scientists must implement sex-responsive periodization models. Tailoring lower-body strengthening and plyometric intensity to individual physiological baselines will ensure balanced neuromuscular adaptations while safeguarding against overuse injuries (Girard et al., 2007; Sogut, 2017).

Despite the valuable longitudinal insights provided by this investigation, several methodological and structural limitations should be acknowledged to contextualize the findings. The sample size ($n=11$), while common for tight longitudinal interventions in specialized sporting populations, reduces statistical power and warrants cautious generalization of the results to broader elite or professional cohorts. Because all participants underwent the 10-week intervention, the study design lacked a matched control group (e.g., non-training or general physical education), which limits the ability to completely rule out external maturation or habituation factors during testing. Neuromuscular assessments were limited to jump height, peak power calculations, and RSI-modified. The integration of force plate technology in future research would allow for deeper diagnostic metrics, such as precise time-to-takeoff, eccentric duration, force-velocity profiling, and impulse distribution. While the introduction and rationale touch upon technical stroke efficiency, overall court mobility, and fatigue management (Bosco et al., 1983; Fernandez-Fernandez et al., 2019; Van Den Berg et al., 2006), these parameters were not direct dependent variables in the current physiological protocol. Furthermore, building upon prior evidence indicating that regular exercise interventions successfully enhance self-esteem and psychological parameters in student cohorts (Yiğiter, 2014; Yiğiter & Hardee, 2017), future research should employ multi-system designs linking RSI-modified directly to 3D motion-capture stroke kinematics and psychological tracking scale outputs.

Conclusions

In conclusion, this study demonstrates that a 10-week tennis-specific training intervention in novice learners drives substantial, highly targeted adaptations in reactive power and stretch-shortening cycle efficiency—as evidenced by marked enhancements in countermovement jump (CMJ) height and modified reactive strength index (RSI-modified). Conversely, non-countermovement performance parameters in squat jumps (SJ) remained essentially unaffected, leaving isolated concentric force production largely unaltered. This physiological dichotomy confirms that while on-court tennis drills serve as powerful drivers of reactive elasticity, field agility, and rapid movement mechanics, they offer insufficient mechanical overload to build raw concentric strength. Furthermore, persistent post-intervention sex differences underscore that sport-specific field drills alone cannot bridge baseline physiological disparities among beginners. Therefore, to build a truly robust athlete and prevent structural imbalances, practitioners must pair on-court tennis training with structured, off-court resistance programming and sex-responsive periodization to optimize lower-body mechanical output and sustain long-term performance gains.

Author Contributions

KY conceptualized and designed the study, performed the training intervention and data collection, analyzed the data, and drafted, revised, and approved the final manuscript.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used generative AI tools solely to refine language, improve readability, and correct grammatical errors; the author reviewed and edited the content and takes full responsibility for the publication.

Data Availability Statement

All relevant data supporting the findings of this study are included within the paper and its Supporting Information files (or available from the corresponding author upon reasonable request).

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Conflicts of Interest

The author declares no conflict of interest regarding the publication of this manuscript.

Supporting Information

S1 Data. Raw dataset for jump performance variables. Excel file containing individual raw measurements (CMJ and SJ parameters) and baseline characteristics of all participants.

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