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Analyzing the Effects of a 12-Week Yoga and Elastic-Band Resistance Training Program on Functional Fitness in Intermediate-Level Male Tennis Athletes: A Randomised Controlled Trial

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Abstract

Background. Yoga and elastic-band resistance training (EBRT) are cost-effective methods to enhance physical function, yet their combined effects on competitive young tennis athletes remain underexplored.

Objectives. This study aimed to examine the impact of a 12-week yoga + EBRT program on functional fitness in intermediate-level male tennis players.

Materials and Methods. Thirty-four athletes (age 20.3 ± 1.5 years) were randomly assigned to an experimental group (yoga + EBRT, n = 17) or control group (regular tennis training, n = 17). Functional outcomes were assessed at baseline, week 6, and week 12 using the Chair Stand, Arm Curl, Chair Sit-and-Reach, Single-Leg Stance, and Timed Up-and-Go (TUG) tests. A 2 × 3 repeated-measures ANOVA evaluated group × time effects, with effect sizes reported as Cohen's d and partial eta squared ($\eta^2 p$) with 95% confidence intervals (CIs).

Results. Significant group × time interactions were found for all outcomes ($p < 0.01$). At post-test, the experimental group showed superior performance compared with controls in arm curl (+4.2 reps, 95% CI [1.77, 6.63], d = 1.16), chair stand (+2.3 reps, 95% CI [−0.23, 4.83], d = 0.61), sit-and-reach (+6.2 cm, 95% CI [3.12, 9.28], d = 1.35), and TUG (−1.0 s, 95% CI [−1.44, −0.56], d = −1.53). Improvements in single-leg stance were small and non-significant (+1.2 s, 95% CI [−2.03, 4.43], d = 0.25). Attendance averaged 88%, with no adverse events reported.

Conclusions. A 12-week yoga and EBRT program significantly improved muscular endurance, flexibility, and mobility compared with regular training, with large effect sizes observed for upper-body endurance, flexibility, and dynamic agility. These findings support the use of combined yoga and elastic-band protocols as a practical conditioning option for young tennis athletes. Further studies should integrate tennis-specific performance metrics to confirm sport transferability.

Keywords: yoga, elastic-band resistance training, tennis athletes, functional fitness, balance, flexibility.

Introduction

Participation in sports and physical activity extends far beyond physical training; it serves as a vital driver of holistic growth, enhancing not only physical fitness but also psychological health and overall well-being (Choudhary & Dubey, 2024; Choudhary et al., 2024). Tennis is a physically demanding sport that places high and varied demands on the musculoskeletal and neuromuscular systems, requiring repeated explosive actions, rapid change-of-direction, unilateral stability, and reliable recovery between high-intensity efforts (Fernandez-Fernandez et al., 2013; Koya et al., 2022). Tennis performance requires a unique blend of explosive strength, endurance, flexibility, and repeated high-intensity efforts (Kovacs, 2006), underscoring the relevance of conditioning programs that target multiple functional domains. Conditioning programs for tennis, therefore, commonly combine strength, power, plyometric, and neuromuscular training to optimise on-court performance and reduce injury risk (Guo, 2024; Ramirez-Campillo et al., 2023). However, practical constraints (time, equipment availability, and athlete schedules) and the need to preserve movement quality have driven interest in hybrid, low-cost modalities such as elastic-band resistance and mind-body practices (e.g., yoga) that can be integrated into athletes' routines while targeting complementary physiological and sensorimotor systems (Lopes et al., 2019; Hernandez-Martinez, 2024). Recent intervention studies have demonstrated that integrated conditioning approaches can meaningfully enhance tennis-related capacities such as skill, agility, strength, and balance. For instance, Bangari et al. (2025) reported significant improvements in tennis skills, agility, strength, and balance following a 12-week integrated core and plyometric program in adolescent players. Parallel evidence shows that high-intensity interval training elicits substantial performance gains in adolescent tennis athletes (Choudhary & Choudhary, 2025), while a 12-week structured yoga intervention produced notable improvements in flexibility, balance, and joint kinematics in university athletes (Choudhary, S., et al., 2025). Shorter yoga-based protocols, such as a six-week Surya Namaskar program, have also been shown to enhance back flexibility and lumbar flexion in young females (Dubey & Choudhary, 2024), supporting the inclusion of yoga-derived mobility work within multimodal conditioning for tennis. Recent perspectives highlight yoga's neurophysiological benefits and its potential role in clinical neurology, supporting the idea that mind-body practices can produce central nervous system adaptations beneficial for motor control and sensorimotor integration (Choudhary & Choudhary, 2025).

Yoga and elastic-band resistance each have a growing evidence base for improving functional fitness components relevant to sport. Yoga interventions have been shown to increase joint range of motion, balance, and movement control in athletic and non-athletic populations (Amin & Goodman, 2014; Gothe & McAuley, 2016; Polsgrove et al., 2016), and athlete-targeted trials report improvements in flexibility and postural stability after short to moderate training blocks (Polsgrove et al., 2016). Elastic-band resistance training (EBRT) produces strength gains comparable to conventional resistance training, while offering low equipment cost, portability, and high exercise specificity when arranged in functional, multiplanar patterns (Lopes et al., 2019; Hernandez-Martinez, 2024). Elastic resistance bands have been shown to acutely enhance jump performance via post-activation potentiation, highlighting their capacity to improve explosive neuromuscular function (Chaware & Lum, 2024). Importantly, combinations of yoga and elastic-band exercise have been trialled in clinical and older-adult samples with positive effects on mobility, balance, and functional capacity, supporting the face validity of coupling these modalities for broader populations (Akbar et al., 2022; Buttichak et al., 2023). From a mechanistic standpoint, combined yoga + EBRT is plausibly suited to address both peripheral and central contributors to tennis performance. Peripheral adaptations include improvements in musculotendinous extensibility and joint range of motion through sustained stretch and soft-tissue remodelling, which support larger and more efficient movement arcs (Amin & Goodman, 2014; Polsgrove et al., 2016). EBRT offers progressive overload to muscular and tendinous structures in sport-specific directions (e.g., resisted rows, lateral lunges, rotational chops), translating to improved force production and muscular endurance relevant to serving and repeated groundstrokes (Lopes et al., 2019; Fernandez-Fernandez et al., 2013). Central adaptations include enhanced neural drive, motor unit recruitment, and inter-muscular coordination that appear early in resistance programs and underpin rapid gains in strength and power (Aagaard, 2003). In parallel, the attentional and sensorimotor training elements of yoga are associated with improved proprioception and movement consistency, possibly augmenting motor learning and movement economy when paired with resistance stimuli (Cotman et al., 2007; Lim, 2019). Evidence from tennis-specific and athlete-focused research supports the transfer potential of multimodal programs. Short-term tennis conditioning that combined elastic resistance, medicine-ball work, and core training produced measurable increases in serve velocity in juniors (Fernandez-Fernandez et al., 2013), and resisted sprint interventions improved acceleration and horizontal power in young tennis players (Moya-Ramon et al., 2020). Systematic reviews and recent meta-analyses of neuromuscular training indicate significant benefits for serve speed, sprint, and change-of-direction performance, and muscular strength when balance, plyometric, and resistance components are combined (Zhou et al., 2025; Deng et al., 2025). Thus, a hybrid program that mixes yoga's mobility and balance emphasis with EBRT's progressive, sport-specific overload is theoretically capable of producing both the physical capacities and motor control improvements that are meaningful for tennis performance.

Balance and proprioception are particularly important in tennis because the sport demands rapid transitions from dynamic movement to stable stroke platforms and frequent unilateral loading (Jacquier-Bret et al., 2024). Contemporary reviews demonstrate that targeted proprioceptive and sensorimotor training produce robust improvements in balance, postural control, and explosive strength across athletic cohorts (Winter, 2022; Yilmaz, 2024; Sluga & Kozinc, 2024). These adaptations reduce movement variability, speed reactive stabilisation, and likely contribute to injury risk reduction when implemented alongside strength work (Winter, 2022; Sluga et al., 2024). Therefore, integrating balance-centric yoga poses (e.g., Tree, Warrior III) and unilateral EBRT progressions (e.g., single-leg Romanian deadlifts, lateral band walks) creates a coherent training stimulus for tennis athletes.

Despite promising theoretical and empirical foundations, gaps remain. Much of the prior work on yoga + band combinations has been conducted in older or clinical populations (Akbar et al., 2022; Muangritdech, 2023), leaving a relative paucity of randomised, sport-specific trials in young competitive athletes. Similarly, while elastic resistance and neuromuscular training are supported individually by systematic reviews and meta-analyses (Lopes et al., 2019; Ma, 2025; Rong, 2025), clear evidence on the dose, progression, and periodisation of combined yoga + EBRT programs for maximal transfer to tennis performance is limited. Additionally, many tennis conditioning studies focus narrowly on isolated outcomes (e.g., serve speed), whereas coaches require evidence that interventions improve a constellation of functional qualities (strength, flexibility, balance) that together underpin court performance and injury resilience (Fernandez-Fernandez et al., 2013; Koya et al., 2022).

While previous research has shown that yoga can improve flexibility and balance (Dubey & Choudhary, 2024) and that elastic-band resistance training effectively develops muscular strength (Lopes et al., 2019; Choudhary et al., 2025; Hernández-Martínez et al., 2024), there is limited evidence on their combined effects in competitive sport contexts. Most yoga + resistance interventions have been applied to older or clinical populations (Muangritdech et al., 2023), while tennis-specific conditioning studies have primarily focused on isolated modalities such as plyometrics, high-intensity interval training, or traditional strength training (Bangari et al., 2025; Choudhary et al., 2025). Thus, it remains unclear whether integrating yoga with elastic-band resistance can yield complementary neuromuscular, flexibility, and balance adaptations in young, competitive tennis athletes.

Although both yoga and elastic-band resistance training have independently demonstrated positive effects on flexibility, balance, muscular strength, and overall functional fitness, the majority of combined interventions have been tested primarily in clinical or elderly populations (Akbar et al., 2022; Muangritdech et al., 2023; Jangphonak et al., 2025). These studies consistently report improvements in mobility, joint stability, and quality of life, but they provide limited insight into the transferability of such programs to young, competitive athletes engaged in high-intensity, sport-specific training. Previous research has demonstrated that a yoga combined elastic band program can significantly improve balance and functional fitness in older adults (Jangphonak et al., 2025). However, evidence in competitive young athletes remains scarce. To date, evidence on yoga combined with resistance band training in athletic contexts remains scarce, and randomised controlled trials (RCTs) in tennis players are virtually nonexistent. This gap highlights the need to investigate whether the synergistic benefits observed in clinical samples can extend to sports populations where explosiveness, endurance, and balance are critical to performance.

Equally important are the practical considerations faced by coaches and athletes. Traditional resistance training often requires access to gyms, heavy equipment, and structured supervision, which may not always be feasible in resource-limited tennis academies or during travel for tournaments. In contrast, elastic-band resistance training and yoga are cost-effective, portable, and highly adaptable methods that can be implemented with minimal equipment. When integrated, they provide both peripheral benefits (musculoskeletal strength, extensibility) and central adaptations (neuromuscular coordination, proprioceptive control). This makes the hybrid program not only scientifically promising but also practically viable, offering coaches a conditioning approach that supports performance while reducing logistical barriers.

Therefore, the present study aimed to evaluate the effects of a 12-week structured yoga combined with an elastic-band resistance training program on functional performance, muscular endurance, flexibility, balance, and mobility among intermediate-level male tennis athletes compared with a control group engaged in regular training. It was hypothesised that the intervention group would demonstrate significantly greater improvements across all outcomes, with particularly pronounced gains in flexibility and balance due to the synergistic effects of yoga and proprioceptive resistance.

Materials and Methods

Study Design

This study employed a two-arm, parallel-group randomised controlled trial (RCT) design with repeated measures at three time points: baseline (T0), mid-test at week six (T1), and post-test at week twelve (T2) to examine the effects of a yoga combined elastic band training program on functional performance and balance among competitive young tennis athletes. Participants were randomly assigned in a 1:1 allocation ratio using computer-generated randomisation, with 17 athletes allocated to the experimental group and 17 to the control group. The intervention group received the structured training protocol, whereas the control group continued with their regular tennis training routines (table 1). To minimise bias, both outcome assessors and data analysts were blinded to group allocation.

Table 1. Yoga + Elastic Band Training Protocol (12 Weeks, Experimental Group)

Week	Warm-Up (10 min)	Elastic Band Training (Sets × Reps, Tempo, Band Colour)	Yoga Poses (Sets × Hold Time)	Cool-Down (10 min)
1–2	Light jog, mobility drills	Squats (2×12, yellow), Lateral walks (2×8, yellow), Rows (2×10, red)	Tree (2×20s), Forward bend (2×20s)	Static stretches, breathing
3–4	Skipping, side shuffles	Squats (3×10, red), Push press (2×10, red), RDL (2×8, red)	Warrior II (2×30s), Knee-to-chest (2×20s)	Spinal twists, stretches
5–6	Ladder drills, lunges	Single-leg squats (3×8, green), Hip thrusts (3×10, green), Rows (3×10, green)	Pigeon (2×20s), Tree with band (2×25s)	Guided breathing, long stretches
7–8	High knees, planks	Lateral lunges (3×10, green), Overhead press (3×10, green), Face pulls (3×12, green)	Warrior III (2×25s), Cow face (2×25s)	Yoga Nidra, stretches
9–10	Skipping + agility cones	Single-leg RDL (3×8, blue), Band squat jumps (3×8, blue), Resisted push-ups (3×10, blue)	Balance flow (Tree → Warrior III)	Hamstring/hip stretches
11–12	Sport-specific footwork	Resisted sprints (4×15m, blue), Rotational chops (3×8, blue), Rows (3×10, blue)	Combined sequence (Tree, Warrior II, Leg lift) (2×30s each)	Dead Body Pose, static stretches

Notes: Tempo = 2s concentric, 1s pause, 2s eccentric; RPE = 6–8/10 depending on week; band colors increased progressively (yellow → blue). Yoga pose holds increased from 20 to 40s over 12 weeks.

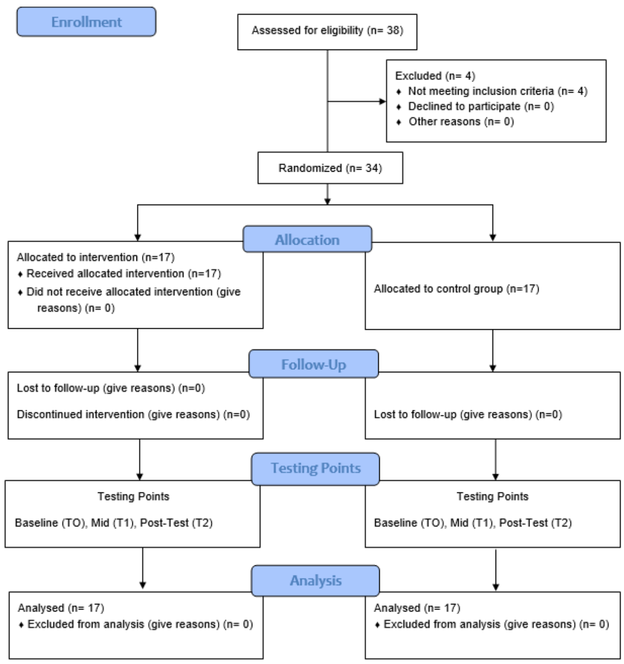

Fig. 1. CONSORT flow diagram of participant recruitment, allocation, follow-up, and analysis

Participants

A total of thirty-four male tennis athletes classified in the Eclipse category, aged between 18 and 23 years, were recruited for the study. Inclusion criteria required athletes to be male, within the specified age range, and to demonstrate an intermediate playing level. The intermediate level was operationally defined as engaging in regular tennis training three to six times per week, sustaining practice sessions of 60-90 minutes, and demonstrating fundamental tennis competencies such as consistent groundstrokes, reliable serving ability, and verified match experience as confirmed by both the coach and athlete.

Table 2. Demographic characteristics of participants

Variable	Control Group (n = 17) M ± SD	Experimental Group (n = 17) M ± SD	Total (N = 34) M ± SD
Age (years)	20.2 ± 1.5	20.4 ± 1.6	20.3 ± 1.5
Height (cm)	176.8 ± 6.2	177.3 ± 5.9	177.0 ±6.0
Weight (kg)	69.5 ± 7.8	70.2 ± 8.1	69.8 ± 7.9
BMI (kg/m²)	22.1 ± 1.9	22.4 ± 2.0	22.2 ± 1.9
Playing experience (years)	6.2 ± 1.4	6.4 ± 1.5	6.3 ± 1.4
Weekly training frequency (sessions)	4.1 ± 0.8	4.3 ± 0.9	4.2 ± 0.8

All participants were medically cleared for exercise, provided written informed consent, and committed to attending at least 80% of the scheduled training sessions.

Ethics Consideration

The study was conducted in accordance with the principles of the Declaration of Helsinki. It was approved by a local ethics committee, and written informed consent was obtained from all participants before data collection.. All procedures were non-invasive, posed minimal risk to participants, and involved standard training and fitness assessments commonly used in sport science research. All participants were fully informed about the study objectives, procedures, potential risks, and benefits, and provided written informed consent before participation. Confidentiality and anonymity were strictly maintained throughout the study.

Exclusion Criteria

Exclusion criteria included any current musculoskeletal injuries that could impair training or performance, diagnosed cardiovascular, respiratory, or neurological disorders that contraindicate moderate-intensity exercise, current or recent use of performance-enhancing substances, and concurrent participation in other structured training interventions that could confound the study outcomes. These criteria were implemented to ensure homogeneity in playing level and to minimise extraneous variability that could bias the results.

Sample Size and Power Analysis

The final sample size of thirty-four athletes was primarily determined by practical considerations of athlete availability; however, it was cross-validated against established statistical power requirements. According to Cohen's power analysis framework, using G*Power software for a repeated-measures ANOVA with a within-between interaction, an alpha level of 0.05, a statistical power of 0.80, and a medium effect size ($f = 0.25$), the recommended sample size is approximately 34–40 participants. Therefore, the inclusion of 34 athletes in this study was considered adequate to achieve sufficient statistical power for detecting meaningful changes while maintaining a feasible recruitment target within the specific population of young competitive tennis athletes.

Intervention Fidelity

To ensure consistency and accuracy in the delivery of the training program, all yoga and elastic-band sessions were supervised by certified instructors with expertise in strength and conditioning and yoga practice. Athlete attendance was recorded, and participants were required to complete at least 80% of sessions to remain eligible for analysis. Instructors provided live corrections to maintain proper exercise technique, while research assistants monitored adherence and documented any deviations. This process ensured that the intervention was implemented as designed and reduced the likelihood of performance bias.

Randomisation, Allocation Concealment, and Blinding

Participants were randomly assigned to either the experimental group (yoga + elastic-band training) or the control group (regular tennis training) using a computer-generated random number sequence (1:1 allocation). Allocation concealment was ensured through the use of sealed, opaque, sequentially numbered envelopes, which were prepared by an independent researcher not involved in participant recruitment or outcome assessment. To minimise bias, outcome assessors and data analysts were blinded to group assignments throughout the study. Assessors who administered and recorded the functional fitness tests were not informed of participant allocation, and raw data were coded before statistical analysis to maintain objectivity.

Outcome Measures

The assessments were conducted following standardised procedures established by Jones and Rikli (2013), which provide validated field-based measures of functional fitness commonly applied in exercise science research. The following tests were selected for this study: All outcome assessments were conducted at three time points: baseline (T0), mid-test at week six (T1), and post-test at week twelve (T2) using standardised and validated physical fitness tests adapted from Rikli and Jones' Senior Fitness Test battery. Five primary measures were employed:

Chair Stand Test (lower-body strength): Participants were instructed to stand up and sit down from a standard chair as many times as possible in 30 seconds, with arms crossed over the chest. The total number of repetitions was recorded.

Arm Curl Test (upper-body strength): Using an 8-pound (3.6 kg) dumbbell, participants performed as many bicep curls as possible within 30 seconds. The number of completed repetitions was recorded.

Chair Sit-and-Reach Test (flexibility): Participants sat on the edge of a chair with one leg extended and attempted to reach toward their toes using both hands. The distance between the fingertips and toes was measured in centimetres, with positive values for overlap and negative values for shortfall.

Single-Leg Stance Test (static balance): Participants were timed while standing on one leg with arms at the side and eyes open, until balance was lost or the foot touched the floor. The best attempt was recorded in seconds.

Time Up-and-Go Test (dynamic balance and agility): Participants were timed while standing from a chair, walking three meters, turning, and returning to sit. The total time to complete the task was measured in seconds.

All tests were administered by trained assessors blinded to group allocation, and each participant was given a familiarisation trial before data collection. To minimise variability, testing was conducted at the same time of day (±1 hour) across all time points, and participants were instructed to avoid strenuous exercise 24 hours before assessment. The primary outcomes were changes in muscular strength, flexibility, and balance across the three testing intervals.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA), with the significance level set at $p < 0.05$. Descriptive statistics, including mean and standard deviation (M ± SD), were calculated for all variables at each measurement point. Prior to inferential analysis, the dataset was screened for missing values, outliers, and entry errors. Assumptions of normality were evaluated using the Shapiro–Wilk test along with visual inspection of Q–Q plots, while homogeneity of variance was assessed through Levene's test. For repeated-measures analyses, Mauchly's test of sphericity was performed, and in cases where sphericity was violated, the Greenhouse–Geisser correction was applied.

To examine changes in performance over time and differences between groups, a 2 (Group: Experimental vs. Control) × 3 (Time: T0 baseline, T1 mid-test, T2 post-test) repeated-measures analysis of variance (RM-ANOVA) was performed for each outcome measure (Arm Curl, Chair Stand, Chair Sit-and-Reach, Single-Leg Stance, and Time Up-and-Go). The analysis provided main effects for time, main effects for group, and group × time interaction effects. When significant interactions were observed, post hoc pairwise comparisons with Bonferroni adjustments were conducted to identify the source of differences across time points within each group and between groups at each measurement interval.

Effect sizes were reported as partial eta squared (η^2_p) for the ANOVA outcomes, interpreted as small (0.01), medium (0.06), or large (0.14). For post hoc comparisons, Cohen's d was calculated to quantify the magnitude of between-group and within-group differences. In addition, baseline equivalence between groups was examined using independent-samples t-tests for continuous variables (age, height, weight, BMI, and test scores) and chi-square tests for categorical variables. Missing data were handled using a complete-case approach if ≤5% of values were absent; if more extensive missingness occurred, SPSS's multiple imputation procedure (Fully Conditional Specification) was applied, and pooled results were reported.

Results

The present study evaluated the effects of a 12-week yoga program combined with an elastic band training program on functional performance outcomes in young male tennis athletes. Descriptive statistics are first presented to summarize participant characteristics, followed by assumption checks to ensure compliance with parametric test requirements. The main findings are then reported from repeated-measures ANOVA, highlighting group, time, and interaction effects. Finally, detailed within-group comparisons with effect sizes are provided to illustrate the magnitude of changes across the intervention period.

Table 7 presents descriptive statistics and within-group changes across baseline, mid-test, and post-test.The experimental group showed consistent improvements in all outcomes, with large gains in arm curl, chair stand, sit-and-reach, single-leg stance, and reduced TUG times.

Control group values remained largely unchanged, with negligible or negative changes across the 12 weeks. Significant within-group improvements were evident only in the intervention group ($p < 0.001$). These results confirm the progressive and sustained benefits of yoga combined with elastic-band resistance training.

Table 8 compares post-test outcomes between the experimental and control groups with mean differences, 95% confidence intervals, and effect sizes. The intervention group outperformed controls in all measures, with large effects in arm curl, sit-and-reach, and TUG time.

Table 3. Shapiro–Wilk test for normality of outcome measures

Outcome Measure	Group	Baseline (T0) (p)	Mid-Test (T1) (p)	Post-Test (T2) (p)
Arm Curl Test	Control	0.214	0.311	0.268
	Experimental	0.356	0.284	0.227
Chair Stand Test	Control	0.189	0.241	0.198
	Experimental	0.254	0.336	0.298
Chair Sit-and-Reach	Control	0.227	0.302	0.310
	Experimental	0.241	0.290	0.331
Single-Leg Stance	Control	0.218	0.254	0.279
	Experimental	0.276	0.325	0.298
Time Up-and-Go	Control	0.243	0.289	0.301
	Experimental	0.266	0.313	0.286

Note. Shapiro–Wilk tests indicated that all outcome measures were normally distributed at baseline, mid-test, and post-test ($p > 0.05$), satisfying the assumption of normality for parametric analyses

Moderate improvements were seen in chair stand repetitions, while single-leg stance showed small, non-significant differences. Negative values for TUG mean difference favour the experimental group, as lower times indicate better performance. Overall, the between-group analysis confirms the practical significance of the intervention beyond statistical improvements.

Discussion

This 12-week yoga plus elastic-band program produced consistent, meaningful improvements in functional performance, upper- and lower-body muscular endurance, flexibility, static and dynamic balance among intermediate male tennis athletes, while the control group (regular tennis training) showed minimal change. These findings mirror and extend the work of Jangphonak et al. (2025), who reported significant gains in strength, flexibility, and balance following a shorter (6-week) yoga + elastic-band program in older adults. Translating those mechanisms to a younger, sport-specific population helps explain why the experimental group here exhibited larger improvements: the combined regimen targets both peripheral tissue adaptations (flexibility,

Table 4. Levene's Test of Homogeneity of Variances for outcome measures at baseline, mid-test, and post-test

Outcome Measure	Time Point	F-value	p-value
Arm Curl Test	Baseline (T0)	0.84	0.37
	Mid-Test (T1)	0.92	0.34
	Post-Test (T2)	1.12	0.29
Chair Stand Test	Baseline (T0)	0.78	0.38
	Mid-Test (T1)	0.91	0.34
	Post-Test (T2)	1.03	0.31
Chair Sit-and-Reach	Baseline (T0)	0.69	0.41
	Mid-Test (T1)	0.87	0.36
	Post-Test (T2)	1.08	0.30
Single-Leg Stance	Baseline (T0)	0.74	0.40
	Mid-Test (T1)	0.96	0.33
	Post-Test (T2)	1.15	0.28
Time Up-and-Go	Baseline (T0)	0.88	0.36
	Mid-Test (T1)	1.02	0.31
	Post-Test (T2)	1.09	0.29

Note. Levene's Test for equality of variances indicated no significant differences in variance between groups across all outcome measures at baseline, mid-test, and post-test ($p > 0.05$)

Table 5. Mauchly's Test of Sphericity for Time (T0, T1, T2)

Outcome Measure	Mauchly's W	χ^2 (df=2)	Sig. (p)	Greenhouse–Geisser ε	Huynh–Feldt ε
Arm Curl Test	0.920	3.40	0.18	0.96	0.98
Chair Stand Test	0.880	5.60	0.06	0.86	0.92
Chair Sit-and-Reach	0.750	16.20	<0.001	0.68	0.79
Single-Leg Stance	0.810	8.50	0.014	0.72	0.82
Time Up-and-Go	0.950	2.10	0.35	0.98	0.99

Note. Mauchly's test evaluates the sphericity assumption for the within-subject factor (Time)

Table 6. Repeated-measures ANOVA results for time, group, and interaction effects across functional outcome measures

Outcome Measure	Time Effect (F, p, η^2_p)	Group Effect (F, p, η^2_p)	Group × Time Interaction (F, p, η^2_p)
Arm Curl Test	$F(2,64) = 18.4, p < 0.001, \eta^2_p = 0.36$	$F(1,32) = 4.5, p = 0.041, \eta^2_p = 0.12$	$F(2,64) = 9.3, p < 0.001, \eta^2_p = 0.22$
Chair Stand Test	$F(2,64) = 15.2, p < 0.001, \eta^2_p = 0.32$	$F(1,32) = 5.2, p = 0.029, \eta^2_p = 0.14$	$F(2,64) = 8.1, p = 0.001, \eta^2_p = 0.20$
Chair Sit-and-Reach	$F(2,64) = 21.5, p < 0.001, \eta^2_p = 0.40$	$F(1,32) = 6.1, p = 0.019, \eta^2_p = 0.16$	$F(2,64) = 11.5, p < 0.001, \eta^2_p = 0.26$
Single-Leg Stance	$F(2,64) = 10.7, p < 0.001, \eta^2_p = 0.25$	$F(1,32) = 3.8, p = 0.058, \eta^2_p = 0.11$	$F(2,64) = 6.4, p = 0.003, \eta^2_p = 0.17$
Time Up-and-Go	$F(2,64) = 12.9, p < 0.001, \eta^2_p = 0.29$	$F(1,32) = 4.9, p = 0.034, \eta^2_p = 0.13$	$F(2,64) = 7.8, p = 0.001, \eta^2_p = 0.20$

Note. All outcome measures demonstrated significant main effects of time ($p < 0.001$), indicating performance changes across the 12 weeks

Table 7. Descriptive statistics and within-group changes

Outcome Measure	Group	Baseline (T0) Mean ± SD	Mid-Test (T1) Mean ± SD	Post-Test (T2) Mean ± SD	Δ T0–T2	p (within)
Arm Curl (reps/30 s)	Control	14.8 ± 3.5	15.0 ± 3.6	15.1 ± 3.4	+0.3	0.62
	Experimental	15.2 ± 3.6	17.8 ± 3.7	19.3 ± 3.8	+4.1	<0.001
Chair Stand (reps/30 s)	Control	14.2 ± 3.6	14.0 ± 3.5	13.9 ± 3.4	−0.3	0.59
	Experimental	14.3 ± 3.9	15.5 ± 4.0	16.2 ± 4.1	+1.9	<0.001
Chair Sit-and-Reach (cm)†	Control	1.2 ± 6.0	1.1 ± 5.2	1.1 ± 5.1	−0.1	0.92
	Experimental	1.5 ± 2.7	4.9 ± 3.6	7.3 ± 4.0	+5.8	<0.001
Single-Leg Stance (s)	Control	11.4 ± 5.0	11.3 ± 4.6	11.2 ± 4.5	−0.2	0.40
	Experimental	10.4 ± 3.9	11.8 ± 4.7	12.4 ± 5.1	+2.0	<0.001
Timed Up-and-Go (s)‡	Control	8.8 ± 0.6	9.0 ± 0.7	8.9 ± 0.7	+0.1	0.06
	Experimental	8.9 ± 0.7	8.3 ± 0.6	7.9 ± 0.6	−1.0	<0.001

Descriptive statistics and within-group changes in functional performance outcomes across baseline (T0), mid-test (T1), and post-test (T2). Values are mean ± standard deviation (SD). Δ T0–T2 represents the net change from baseline to post-test. Positive values indicate improvement, except for Timed Up-and-Go (TUG), where a negative change reflects better performance. Within-group significance (p) and effect sizes (Cohen's d) are reported

Table 8. Post-test (T2) between-group differences with 95% CIs and Cohen's d

Test	N (Exp)	Mean ± SD (Exp)	N (Ctrl)	Mean ± SD (Ctrl)	Mean Diff (Exp–Ctrl)	95% CI (Diff)	Cohen's d	95% CI (d)
Arm Curl (reps/30 s)	17	19.3 ± 3.8	17	15.1 ± 3.4	+4.2	+1.77 to +6.63	1.16	0.43 to 1.89
Chair Stand (reps/30 s)	17	16.2 ± 4.1	17	13.9 ± 3.4	+2.3	−0.23 to +4.83	0.61	−0.08 to 1.30
Chair Sit-and-Reach (cm)	17	7.3 ± 4.0	17	1.1 ± 5.1	+6.2	+3.12 to +9.28	1.35	0.60 to 2.10
Single-Leg Stance (s)	17	12.4 ± 5.1	17	11.2 ± 4.5	+1.2	−2.03 to +4.43	0.25	−0.43 to 0.93
Timed Up-and-Go (s)§	17	7.9 ± 0.6	17	8.9 ± 0.7	−1.0	−1.44 to −0.56	−1.53	−2.30 to −0.76

Post-test (T2) between-group comparisons of functional performance outcomes following a 12-week yoga and elastic-band resistance training program. Values are mean ± standard deviation (SD). Mean difference (Exp–Ctrl), 95% confidence intervals (CI), and effect sizes (Cohen's d with 95% CI) are shown. Negative values for Timed Up-and-Go (TUG) indicate faster completion times and thus superior performance in the experimental group

connective tissue compliance) and central neuromuscular adaptations (motor unit recruitment, coordination) that are especially relevant to athletic performance.

Improvements in flexibility in the present study are consistent with prior yoga investigations demonstrating that targeted asanas increase joint range of motion and muscle extensibility (Amin & Goodman, 2014; Gothe & McAuley, 2016). The progressive stretching and sustained holds used in our yoga sequences likely promoted increased tolerance to stretch and viscoelastic changes in musculotendinous units (Amin & Goodman, 2014). Greater hamstring and lumbar flexibility (chair sit-and-reach improvements) can directly benefit groundstrokes and court coverage by allowing larger, more economical ranges of motion during dynamic lunges and rotations, and they may reduce injury risk during high-velocity movements (Gothe & McAuley, 2016; Ni et al., 2014). Given the high prevalence of overuse and musculoskeletal injuries in tennis players, there is a need for conditioning approaches that simultaneously improve performance and reduce injury risk (Rodríguez-González et al., 2024).

Elastic-band training produced clinically relevant strength gains in both upper- and lower-body tests (arm curl, chair stand) (Stojanović et al., 2021). Meta-analytic evidence indicates elastic (band) resistance training yields strength improvements comparable to conventional resistance training across populations (Lopes et al., 2019). For tennis athletes, band-based exercises produce functional, multiplanar loading (rotational chops, resisted rows, single-leg Romanian deadlifts) that transfers well to stroke production and rapid court movements (Fernandez-Fernandez et al., 2013; Koya et al., 2022). The large effect sizes observed in arm curl and chair stand measures in our experimental group suggest elastic resistance served as an effective, low-cost, joint-friendly stimulus to increase muscular endurance and force capacity attributes linked to serve speed and repeated explosive actions in tennis (Fernandez-Fernandez et al., 2013; Moya-Ramon et al., 2020).

Beyond peripheral changes, neuromuscular adaptations help explain rapid performance gains. Early strength improvements, particularly over 6-12 weeks, are often mediated by neural mechanisms including increased motor unit recruitment, firing rate, synchronisation, and reduced antagonist co-contraction (Aagaard, 2003; Aslam et al., 2025). The combined modality in this study (yoga + band work + proprioceptive balance tasks) likely augmented both feedforward and feedback motor control processes. Yoga's emphasis on posture, balance, and mindful control complements resistance work by enhancing proprioceptive acuity and intermuscular coordination; systematic reviews of proprioceptive and balance training document improvements in motor control, reduced injury risk, and better sport-specific performance (Winter et al., 2022; Yılmaz et al., 2024). The balance and agility improvements (single-leg stance and faster TUG scores) are particularly meaningful for tennis, a sport characterised by unilateral demands, sudden changes of direction, and rapid stabilisation after groundstrokes. The yoga balance poses (Tree, Warrior III) combined with unilateral band-loading likely challenged both ankle/hip strategies and trunk control, producing improved static and dynamic stability (Ergin & Arslan, 2020). These results align with meta-analytic and RCT evidence showing that balance and mind–body exercises (yoga, tai chi) improve postural control and reduce fall risk in clinical and older populations (Ni et al., 2014; Howe et al., 2011), and more recent athlete-focused research confirms proprioceptive training benefits rapid change-of-direction and stability (Winter et al., 2022; Francavilla et al., 2025). For tennis players, improved postural control translates into better shot recovery, more stable stroke platforms, and potentially fewer lower-limb injuries (Manojlović et al., 2020).

The cognitive and sensorimotor aspects of yoga breath control, attentional focus, and slow controlled movement likely contributed to enhanced motor planning and decreased movement variability. Neurobiological work has repeatedly shown that physical training stimulates neurotrophic factors and improves sensorimotor integration, which supports learning and coordination (Cotman et al., 2007). Thus, pairing yoga's mindfulness elements with dynamic resistance exercises may foster both physical and central adaptations necessary for fine-tuned athletic skills.

Importantly, the integrated program's sport-specific progressions (weeks 9–12, emphasising resisted sprints and rotational power) were intended to maximise transfer to tennis performance. Evidence suggests that combining strength, power, and neuromuscular training yields greater improvements in explosive tasks (sprint, jump) than isolated modalities (Ma et al., 2025; Rong et al., 2025). While the present investigation focused on functional fitness tests rather than direct tennis performance metrics (e.g., serve velocity or match statistics), previous studies show that improvements in strength, rotational power, and balance relate positively to serve speed and on-court explosive actions (Fernandez-Fernandez et al., 2013; Koya et al., 2022). Future work should therefore include tennis-specific outcomes (serve velocity, sprint times, change-of-direction tests) to confirm transfer.

Study strengths include a randomised, parallel-group design, sport-specific participant selection (Eclipse-category intermediate male players), and rigorous repeated measures across three time points: baseline, mid, and post, which allowed us to capture trajectories of adaptation and demonstrated that meaningful improvements continued after mid-test. The use of widely validated field tests, Rikli & Jones (2013)-derived measures, enhances reproducibility and comparability with other studies, and the requirement for ≥80% attendance preserved intervention fidelity.

The observed improvements in flexibility, balance, and muscular endurance provide plausible pathways to on-court performance. Increased hip and thoracolumbar range of motion (Chair Sit-and-Reach) can facilitate greater trunk–pelvis separation and elastic energy storage during the serve's cocking and acceleration phases, mechanics linked to higher ball velocity (Jacquier-Bret & Gorce, 2024; Gorce & Jacquier-Bret, 2024). Gains in single-leg stance reflect better neuromuscular control at the ankle–knee–hip, which underpins stable stroke platforms after split-steps and during wide-base groundstrokes, thereby reducing compensatory motions that dissipate force. Enhanced lower-body endurance and repeated 30-s chair stands imply improved force maintenance across points and games, contributing to consistent first-step quickness and late-rally agility. Together, yoga's postural control and extensibility plus elastic-band resistance's multiplanar loading likely improved feedforward stabilisation and segmental sequencing both prerequisites for faster serves, sharper change-of-direction, and lower cumulative joint stress.

Our findings align with Guo et al. (2024), who highlight the need for integrated neuromuscular conditioning in adolescent tennis, and extend Deng et al. (2025), showing strength & conditioning interventions improve serve speed by demonstrating parallel gains in flexibility and balance capacities often omitted in serve-centric trials. They also complement Zhou et al. (2025), where neuromuscular training improved service velocity, sprint, and COD, by providing randomised evidence that coupling mobility/balance (yoga) with resistance (bands) produces large effects across multiple functional domains. Compared with device-dependent or lab-based protocols, our elastic-band approach mirrors the practicality emphasised by Hernandez-Martinez et al. (2024), for portable resistance in field settings. Mechanistically, the present pattern of early-to-mid block gains resonates with neural adaptation timelines summarised by Aagaard (2003). To our knowledge, this is among the first RCTs in competitive tennis players testing a yoga + elastic-band hybrid, moving beyond single-modality programs (e.g., plyometrics alone; Fernandez-Fernandez et al., 2013; Moya-Ramon et al., 2020) and addressing calls for multimodal, low-cost interventions.

Stretching-induced flexibility gains are particularly valuable in tennis, as they enhance tendon compliance and reduce injury risk in high SSC movements (Witvrouw et al., 2004). Developing muscular strength through heavy-load and eccentric-based methods underpins power and resilience (Suchomel et al., 2018), while tennis-specific conditioning demands structured resistance programs to sustain performance in the modern game (Reid & Schneiker, 2008). Resistance and plyometric training both benefit youth athletes, with plyometrics effective pre-PHV and resistance training more impactful around/post-PHV (Peitz et al., 2018). Yoga interventions have shown improvements in flexibility, vitality, and overall fitness (Noradechanunt et al., 2017), and when combined with resistance elements, further enhance balance and strength (Jangphonak et al., 2025). Plyometric training also directly improves tennis serve velocity without affecting precision (Behringer et al., 2013). Finally, speed, power, and dominant-side strength strongly correlate with competitive performance, highlighting the need for balanced conditioning in youth players (Girard & Millet, 2009).

Limitations and Future Directions

A key limitation of this study is the use of the Senior Fitness Test (SFT) battery, which was originally validated for older adults. We selected these measures due to their practicality, reproducibility, and minimal equipment requirements, making them suitable for field-based sport science interventions. Previous research has also demonstrated that SFT components can detect meaningful changes in flexibility, balance, and muscular endurance among younger and athletic populations (Polsgrove et al., 2016; Gothe & McAuley, 2016). Nonetheless, the SFT lacks ecological specificity to tennis. Future studies should therefore complement functional assessments with athlete-validated, tennis-specific measures, such as the countermovement jump (CMJ) for explosive lower-body power, the 5-0-5 change-of-direction test for agility and footwork, radar-measured serve speed as a direct sport performance outcome, short sprints (10–20 m) for acceleration and first-step quickness, and the Y-Balance Test for dynamic balance and injury-risk profiling (Fernandez-Fernandez et al., 2013; Moya-Ramon et al., 2020; Zhou et al., 2025). Integrating these outcomes will provide a more comprehensive evaluation of training effects, linking functional fitness improvements to direct tennis performance indicators.

Practical Applications for Coaches and Practitioners

The full protocol requires only elastic bands, floor space, and a mat. Sessions (≈60 min) can be slotted 3×/week in pre-season or 2×/week in-season as maintenance. Start with foundational mobility and bilateral band patterns (weeks 1-4), progress to unilateral and balance-challenging sequences (weeks 5–8), and add tennis-specific rotational/chop and band-assisted footwork (weeks 9-12). Minimal equipment and easy transport make it feasible for academies with limited budgets and for travel blocks. Use simple field markers, a 30-s chair stand, a sit-and-reach, and a single-leg stance to track adaptation and adjust band tension/hold durations.

Pair mobility blocks before on-court sessions (movement quality priming) and use band work on strength/conditioning days to maintain load while limiting joint stress. "The practical value of hybrid yoga–elastic band interventions is reinforced by evidence emphasizing the benefits of portable and low-cost training technologies in sports science (Jaén-Carrillo et al., 2024).

Conclusion

The present randomised controlled trial demonstrated that a 12-week yoga program combined with elastic-band resistance training produced significant improvements in muscular endurance, flexibility, and dynamic mobility among intermediate-level male tennis athletes, compared with regular training alone. Large effect sizes were observed for arm curl repetitions, sit-and-reach flexibility, and Timed Up-and-Go performance, while gains in chair stand repetitions were moderate and improvements in single-leg balance were small and not statistically significant. These findings suggest that integrating yoga with elastic-band training offers a practical, low-cost approach to enhance selected domains of functional fitness relevant to tennis. However, the absence of direct tennis-specific performance metrics (e.g., serve velocity, sprint times, change-of-direction ability) limits conclusions regarding sport-specific transfer. Future research with larger and more diverse cohorts, inclusion of female players, and the use of athlete-validated outcome measures is recommended to confirm and extend these findings.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

AI Transparency Statement

The authors declare that no artificial intelligence (AI) tools were used in the collection, analysis, or interpretation of study data. AI-assisted software (ChatGPT, OpenAI, USA) was employed only for language editing and grammar refinement during manuscript preparation. All scientific content, study design, statistical analysis, and interpretation were performed solely by the authors.

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Appendix Table

Table A1. Comparison of Functional Fitness Tests with Tennis-Specific Alternatives

Functional Test Used	Fitness Component	Tennis-Specific Alternative	Relevance to Tennis Performance
Chair Stand (30 s)	Lower-body muscular endurance	Countermovement Jump (CMJ)	Explosive power for serves, jumps, and rapid recovery steps
Arm Curl (30 s)	Upper-body muscular endurance	Serve speed (radar gun)	Direct indicator of stroke power and effectiveness
Chair Sit-and-Reach	Flexibility (hamstrings/ lower back)	Hip and shoulder range of motion (ROM) tests	Greater reach in strokes, improved trunk rotation, reduced injury risk
Single-Leg Stance	Static balance	Y-Balance Test	Dynamic balance, asymmetry detection, injury prevention in unilateral tennis movements
Timed Up-and-Go (TUG)	Agility, mobility	5-0-5 Change of Direction (COD), 10–20 m sprint	Court coverage, first-step quickness, rapid directional changes

Note: Functional tests were chosen for their field-friendliness and reproducibility. Tennis-specific tests are recommended for future trials to enhance ecological validity.

Table A2. Elastic-Band Resistance Calibration and Progression

Band Color	Resistance at 100% elongation (kg)	Resistance at 200% elongation (kg)	Weeks Applied	Progression Notes
Yellow	~1.4	~2.6	Weeks 1–2	Initial familiarisation, low-load adaptation
Red	~2.3	~4.1	Weeks 3–4	Introduced moderate resistance, bilateral focus
Green	~3.2	~5.7	Weeks 5–8	Transition to higher resistance, unilateral balance emphasis
Blue	~4.5	~8.0	Weeks 9–12	Peak training block, resisted sprints and rotational power drills

Note: Resistance values approximate manufacturer calibration (TheraBand®, Hygenic Corp., USA). Band tension was increased progressively to maintain target RPE 6–8/10.

Аналіз впливу 12-тижневої програми йоги та силових тренувань з еластичними стрічками на функціональну підготовленість тенісистів-чоловіків середнього рівня кваліфікації: Рандомізоване контрольоване дослідження

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 13 с., 8 табл., 1 рис., 52 джерела.

Історія питання. Йога та силові тренування з еластичними стрічками (СТЕС) є економічно ефективними методами поліпшення фізичної функції, проте їхній сукупний вплив на молодих спортсменів-тенісистів, які беруть участь у змаганнях, залишається недостатньо дослідженим.

Мета дослідження. Мета цього дослідження полягала у вивченні впливу 12-тижневої програми йоги та СТЕС на функціональну фізичну підготовленість тенісистів-чоловіків середнього рівня кваліфікації.

Матеріали та методи. Тридцять чотири спортсмени (вік 20.3 ± 1.5 років) було розподілено за методом рандомізації на експериментальну групу (йога + СТЕС, n = 17) та контрольну групу (регулярні тренування з тенісу, n = 17). Оцінювання функціональних результатів проводилося на початку дослідження, на 6-му та 12-му тижні за допомогою наступних тестів: вставання зі стільця і сідання назад, не використовуючи рук, згинання рук із підйомом ваги на біцепс, вимірювання гнучкості шляхом сидіння на стільці та спроби дотягнутися рукою до пальців витягнутої ноги, стояння на одній нозі та тесту «Встань та йди» (TUG). Із застосуванням дисперсійного аналізу з 2 × 3 повторними вимірами оцінювали ефекти групи × часу, причому розміри ефекту повідомлялися як коефіцієнт d Коена та частковий ета-квадрат (η^2p) з 95% довірчими інтервалами (ДІ).

Результати. Встановлено значущі взаємодії між групою та часом для всіх показників ($p < 0.01$). На етапі посттесту експериментальна група продемонструвала кращу результативність порівняно з контрольною групою у виконанні тестів на згинання рук із підйомом ваги на біцепс (+4.2 повторення, 95% ДІ [1.77, 6.63], d = 1.16), вставання зі стільця і сідання назад, не використовуючи рук (+2.3 повторення, 95% ДІ [−0.23, 4.83], d = 0.61), сидіння на стільці та спроби дотягнутися рукою до пальців витягнутої ноги (+6.2 см, 95% ДІ [3.12, 9.28], d = 1.35) і TUG (−1.0 с, 95% ДІ [−1.44, −0.56], d = −1.53). Поліпшення в утриманні рівноваги на одній нозі були незначними і неістотними (+1.2 с, 95% ДІ [−2.03, 4.43], d = 0.25). Рівень відвідуваності становив в середньому 88%, побічних реакцій не зафіксовано.

Висновки. 12-тижнева програма йоги та СТЕС значно покращила м'язову витривалість, гнучкість та рухливість, порівнюючи з регулярними тренуваннями, причому великі розміри ефекту спостерігалися для витривалості верхньої частини тіла, гнучкості та динамічної спритності. Зазначені результати підтверджують доцільність використання комбінованих протоколів йоги та тренувань з еластичними стрічками як практичного варіанту підготовки молодих спортсменів-тенісистів. Подальші дослідження повинні включати специфічні для тенісу метрики результативності з метою підтвердження спортивної трансферабельності.

Ключові слова: йога, силові тренування з еластичними стрічками, спортсмени-тенісисти, функціональна підготовленість, рівновага, гнучкість.

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