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Effects of physical performance improvements on football-tennis technical skills in middle-school students

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Abstract

Aim. The aim of this study was to evaluate the effects of an 8-week football-tennis training program, implemented during physical education classes, on physical performance (vertical jump height, 20 m sprint time, change-of-direction time, jump endurance, reactive strength index) and technical skills (service accuracy, total volleys, longest rally, controlled receiving) in untrained rural middle-school boys.

Material and method. Twenty-six male students aged 13–15 years completed a pre–post intervention consisting of two football-tennis–based sessions per week within regular PE lessons. Physical performance was assessed using standardized field tests, while technical skills were evaluated through accuracy- and consistency-based football-tennis tasks. Height and body weight were also recorded.

Results. Vertical jump height increased from 27.07 to 30.39 cm, 20 m sprint time improved from 3.86 to 3.57 s, and change-of-direction time decreased from 14.67 to 13.82 s. Jump endurance rose from 27.15 to 31.38 repetitions, and reactive strength index increased from 1.46 to 1.71. Technical performance showed selective improvements: total volleys increased from 32.6 to 39.7 and longest rally from 12.3 to 17.5 (both statistically significant). In contrast, service accuracy (70.0% to 69.5%) and controlled receiving (74.8% to 74.3%) did not vary statistically significantly.

Conclusions. The training program produced clear gains in explosive strength, sprint speed, agility, jump endurance, and reactive ability, and moderate improvements in volley-related technical performance. However, precision-based skills such as service accuracy and controlled receiving remained statistically unchanged, suggesting that longer or more specialized technical practice may be necessary. These findings support the integration of structured football-tennis training within school physical education programs.

Key words: *football-tennis, reactive strength, sprint ability, technical accuracy, school-based training*

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Introduction

Football-tennis is a technically demanding acyclic sport requiring rapid perceptual-motor processing, explosive lower-limb actions, and strong coordination across offensive and defensive phases, making the optimization of physical and technical qualities central to performance (Țifrea & Gherghel, 2020). Research in elite athletes shows that training combining plyometrics with sport-specific drills substantially improves explosive force, jump height, and reactive strength (Gherghel et al., 2021). Periodized microcycles integrating sprint tasks, lateral displacements, and dynamic skill rehearsals similarly enhance speed, flexibility, and mobility in football-tennis players (Țifrea et al., 2021). Evidence from junior athletes highlights that targeted explosive-leg conditioning improves technical execution—especially pressing-skill accuracy—demonstrating transfer from neuromuscular adaptations to ball control (Breesim & Majeed, 2024). Youth studies also show strong links between agility, flexibility, responsiveness, and preparation-skill accuracy, emphasizing the contribution of general motor abilities to sport-specific performance (Abid Aoun & Katea, 2024). Beyond elite contexts, match-analysis-derived exercise models indicate that conditioning aligned with competitive demands improves speed, agility, explosive efforts, and endurance in young players (Hussain & Khither, 2024). These findings are consistent with broader evidence that plyometric jump training produces moderate but reliable gains in reactive strength index (RSI) across ages and sports (Ramirez-Campillo et al., 2023). RSI also correlates meaningfully with acceleration, top speed, COD ability, and muscular strength, making it a sensitive marker for adaptations to high-speed neuromuscular training (Jarvis et al., 2022). The countermovement jump (CMJ) remains a key assessment of explosive performance, with recent work recommending reliable CMJ-derived variables—such as jump height and RSI—for applied monitoring (Anicic et al., 2023).

School-based settings offer an accessible platform for structured interventions, as nearly all children participate in physical education (Slingerland & Borghouts, 2011). PE-based programs have increased motor engagement and MVPA, particularly when teachers use active-learning strategies (Lonsdale et al., 2013). Cooperative-learning approaches further enhance motivation and emotional intelligence, supporting positive behavioral outcomes (Rivera-Pérez et al., 2021). Activity levels in primary and middle-school students depend heavily on school context, curricular structure, and access to structured motor tasks (Cocca et al., 2021), and technological tools such as wearable inertial sensors can provide reliable biomechanical feedback to track movement quality and asymmetries (López-Fernández et al., 2022). Overall, evidence suggests that structured school-based programs integrating physical conditioning and technical training can meaningfully improve youth performance, even among non-athletes. However, despite growing research in elite and junior football-tennis, little is known about how short-term, curriculum-compatible programs affect physical and technical outcomes in untrained middle-school pupils. This gap is important because football-tennis skills—such as serving accuracy, controlled receiving, and volley consistency—require fine motor coordination that may develop differently from basic physical attributes. Moreover, adolescents in rural environments often lack access to specialized coaching, underscoring the need for feasible field-based models. Football-tennis, as a technically demanding acyclic sport, requires a combination of explosive lower-limb actions, precise motor control, and efficient biomechanical execution, similar to other ball-based invasion games taught in school physical education. Recent educational research highlights that structured pedagogical interventions significantly improve technical execution and biomechanical efficiency in youth when training is adapted to developmental stages (Gherman et al., 2025). Moreover, biomechanical feedback and targeted drills have been shown to enhance movement quality and technical accuracy in school-aged students, even in non-competitive settings (Gherman & Gomboș, 2018).

Given the sport's dual demands for explosive actions and technical precision, integrated pre-post testing of vertical jump metrics, sprint speed, COD efficiency, jump endurance, RSI, and football-tennis-specific skills offers a comprehensive view of adaptations. Therefore, this study examines the effects of an 8-week structured program delivered in regular PE classes on physical and technical performance in untrained rural middle-school boys. Drawing on elite football-tennis research (Gherghel et al., 2021; Țifrea et al., 2021), youth motor-skill literature (Abid Aoun & Katea, 2024), match-analysis-based conditioning models (Hussain & Khither, 2024), and school-based intervention work (Slingerland & Borghouts, 2011; Lonsdale et al., 2013), it aims to provide context-specific insights relevant to PE, talent development, and youth sports training.

Aim

The purpose of this study was twofold. (1) It first aimed to examine how an 8-week football-tennis program delivered during regular physical education classes influenced the physical performance of untrained rural middle-school boys by tracking changes in vertical jump height, 20 m sprint time, change-of-direction speed, jump

endurance, and reactive strength index through standardized pre–post testing. This objective sought to determine how non-athlete pupils without formal training could enhance key neuromuscular and locomotor capacities in a school-based setting. (2) The second aim was to evaluate whether these physical improvements would translate into better football-tennis technical abilities—specifically service accuracy, total volleys, longest rally, and controlled receiving, all dependent on coordination, timing, and fine motor control. A further objective was to explore whether gains in explosive power, speed, and reactive ability transferred more effectively to dynamic rally-based actions than to precision-oriented skills. The selection of jump-based neuromuscular indicators such as vertical jump height and reactive strength index is supported by previous research demonstrating their sensitivity to training-induced adaptations in youth athletes. Neuromuscular coefficients derived from jump assessments have been shown to reflect meaningful changes in force–speed relationships and power output following structured training programs (Gherman & Gomboș, 2018).

Materials and method

Participants

The participants were middle-school pupils from rural Romania, aged 12 to 15 years, all of whom were boys. They practiced football-tennis only occasionally, primarily during physical education classes, and had no formal training background in the sport. None of the participants were registered as competitive athletes in any sport or affiliated with any sports club or association.

Study design

The study employed a pre–post intervention design in which all participants underwent a baseline assessment followed by an identical post-intervention evaluation after an 8-week structured training period. The protocol targeted multiple domains of performance relevant to football-tennis, encompassing anthropometric profiling (HT, WT), physical performance metrics—vertical jump height (VJH), 20-m linear sprint time (SP20), change-of-direction speed (COD), total jump count (JC), and reactive strength index (RSI)—as well as task-specific technical skills including service accuracy (SERVICE), 60-s volley performance (VOL_TOT), longest consecutive rally (VOL_BEST), and controlled receive-and-send accuracy (CONTROL). All assessments were performed under standardized conditions in the school gymnasium or outdoor sports area, ensuring environmental and procedural consistency across testing sessions.

Training Protocol

The intervention consisted of an 8-week training program delivered exclusively within regularly scheduled physical education classes, following the structure and time allocation of the national school curriculum. Training sessions were held twice per week, lasted 45–50 minutes, and followed a periodized format. Each session began with a neuromotor warm-up emphasizing dynamic mobility, low-impact plyometrics, and coordination tasks tailored to football-tennis demands. The main component focused on technical skill acquisition through progressive serving drills, controlled volleying sequences, footwork patterns, and receive–redirect exercises, gradually advancing to situational game-based drills to stimulate decision-making and perceptual–motor coordination. To improve the physical variables measured, the program incorporated submaximal plyometric sequences (e.g., repeated vertical jumps enhancing JC and RSI), short sprint bursts aligned with SP20 requirements, and agility circuits targeting COD performance. Training intensity remained moderate to ensure safety and accessibility for adolescents, emphasizing technical refinement and movement quality rather than high-volume conditioning.

Data collection procedures

Anthropometric measurements were obtained with standardized field instruments: stature (HT) was recorded using a wall-mounted stadiometer to the nearest 0.1 cm, and body mass (WT) with a calibrated digital scale accurate to 0.1 kg. Physical performance metrics were assessed with validated field-based methods. VJH and RSI were derived from countermovement and drop-jump trials on a contact platform or jump mat capable of measuring flight time and calculating take-off displacement and reactive strength with millisecond precision. SP20 was measured using handheld digital stopwatches operated by trained assessors or, when available, dual-beam electronic timing gates to reduce reaction-time error. COD performance was evaluated on a standardized agility course (e.g., modified T-test or shuttle protocol), with time recorded to the nearest 0.01 s. JC represented the total number of correctly executed vertical jumps within a set interval, counted manually by trained observers. Technical football-tennis metrics were obtained through structured skill-assessment stations: SERVICE accuracy was the percentage of serves landing in a target zone out of 50 attempts; VOL_TOT and VOL_BEST came from a 60-second continuous volleying task counting total contacts and longest sequence; and CONTROL accuracy was measured using a 50-ball receive-and-redirect protocol based on successful deliveries into a marked target area. All technical assessments used identical procedures in pre- and post-testing to ensure reliability and repeatability.

Statistical analysis

The statistical analysis combined descriptive procedures—including means, standard deviations, distribution summaries, and graphical representations (boxplots and bar charts)—with inferential tests to evaluate pre–post changes across all physical and technical parameters. Paired-samples t-tests were applied to both absolute values and percentage changes to determine the statistical significance of differences between initial and final assessments. All analyses were performed in STATA 18, which served as the primary environment for data processing, visualization, and inferential computation.

Results

Interpreted descriptive statistics of performance outcomes

The descriptive statistics (table 1) provides a clear overview of the athletes’ physical characteristics and performance changes across all measured variables. The mean HT is 167.84 cm, with values ranging from 153.9 cm to 186.8 cm, indicating a relatively broad height distribution within the group. Similarly, WT shows a mean of 67.0 kg, spanning from 49.0 kg to 82.0 kg, with an interquartile range (IQR) roughly between 59.75 kg and 74.75 kg. The initial vertical jump, VJH_I, has a mean of 27.07 cm, increasing to 30.39 cm in VJH_F, where the median improves from 26.04 cm to 29.62 cm, reflecting clear gains in lower-limb power. The maximum jump height also rises substantially from 35.91 cm to 38.52 cm, suggesting that top performers achieved notable progress. Sprint performance also improves: SP20_I has a mean time of 3.86 s, which decreases to 3.57 s in SP20_F, with minimum values dropping from 3.36 s to 2.98 s, marking faster acceleration. The median sprint time shows a similar reduction from 3.88 s to 3.60 s, indicating consistent improvements across most participants. Agility, measured by COD_I, starts at a mean of 14.67 s and decreases to 13.82 s in COD_F, with the lowest recorded time improving from 12.99 s to 11.61 s. The jump endurance variable, JC_I, shows a mean of 27.15 jumps rising to 31.38 jumps in JC_F, with the best performer increasing from 36 to 45 jumps, marking substantial progress in repeated power output. Finally, RSI_I improves from a mean of 1.46 to 1.71 in RSI_F, with the 75th percentile increasing from 1.66 to 1.94, indicating enhanced reactive strength across higher-performing athletes. Overall, the table highlights consistent upward trends in all final performance measures, confirming effective adaptation to training.

Table 1. Descriptive statistics for football-tennis dataset

Variable	Mean	SD	Min	25%	50%	75%	Max
Height_cm (HT)	167.84	10.73	153.9	157.1	166.95	177.98	186.8
Weight_kg (WT)	67.0	10.5	49.0	59.75	66.5	74.75	82.0
VJH_initial (VJH_I)	27.07	3.73	22.11	24.42	26.04	30.0	35.91
VJH_final (VJH_F)	30.39	4.16	23.21	27.6	29.62	32.88	38.52
Sprint20_initial (SP20_I)	3.86	0.32	3.36	3.56	3.88	4.14	4.29
Sprint20_final (SP20_F)	3.57	0.3	2.98	3.36	3.6	3.83	3.99
COD_initial (COD_I)	14.67	1.14	12.99	13.46	15.04	15.49	16.11
COD_final (COD_F)	13.82	1.26	11.61	12.79	13.93	14.87	15.64
JumpCount_initial (JC_I)	27.15	5.86	18.0	23.0	25.5	33.0	36.0
JumpCount_final (JC_F)	31.38	7.43	20.0	25.0	30.0	37.75	45.0
RSI_initial (RSI_I)	1.46	0.26	0.93	1.32	1.5	1.66	1.87
RSI_final (RSI_F)	1.71	0.33	1.16	1.48	1.72	1.94	2.4

The paired boxplots for SP20 and RSI (figure 1) illustrate distinct and meaningful improvements in both sprint performance and reactive strength over the training period. For SP20, the initial median time is close to 3.9 seconds, while the final median drops to about 3.6 seconds, showing a clear enhancement in short-distance acceleration. This downward shift in the entire distribution indicates that the improvement was not limited to a few athletes; rather, most participants became faster. The upper whisker also moves noticeably lower, suggesting that even the slowest performers reduced their sprint times. In contrast, the spread of the final SP20 values is slightly more compact, hinting at a more homogeneous sprint ability across the group after training. For RSI, the median increases from roughly 1.5 to 1.7, reflecting stronger elastic energy utilization and improved stretch-shortening cycle function. The higher upper whisker in the final RSI distribution shows that some athletes achieved values above 2.0, indicating substantial gains in reactive strength. Although the variability slightly increases, this may simply suggest different degrees of neuromuscular adaptation within the group rather than inconsistencies.

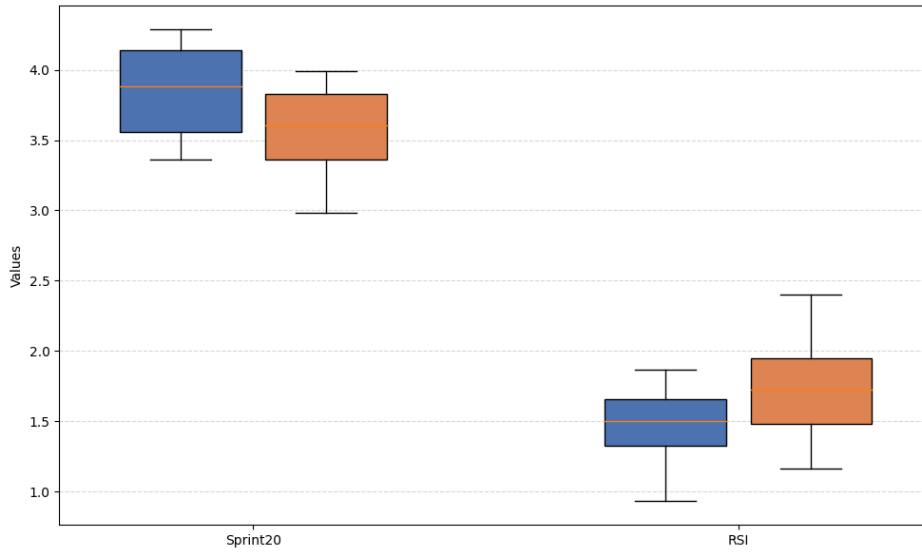


Fig 1. Boxplot for Sprint20 & RSI, initial vs final

Figure 2, which groups VJH, COD, and JC, provides a broader overview of improvements across lower-limb power, agility, and repetitive jump ability. VJH shows a strong upward shift: the median increases from around 26 cm initially to nearly 30 cm at the final test, signaling enhanced explosive strength. The upper range extends past 35 cm in the final results, indicating some standout performers who made particularly notable gains. For COD, the median time declines from approximately 15.0 s to 13.9 s, demonstrating improvements in change-of-direction speed and coordination. This reduction is important because COD tasks rely on both neuromuscular efficiency and directional control, suggesting multidimensional progress. Meanwhile, JC displays the most dramatic change: the median increases from about 25 jumps to roughly 30 jumps, and the upper whisker reaches 45 jumps, showing significant enhancement in repeated power output. This pattern suggests that the training program effectively targeted both explosive and endurance-based jump capacities. Together, these figures clearly illustrate comprehensive physical development across key performance variables, supporting the effectiveness of the 8-week training intervention.

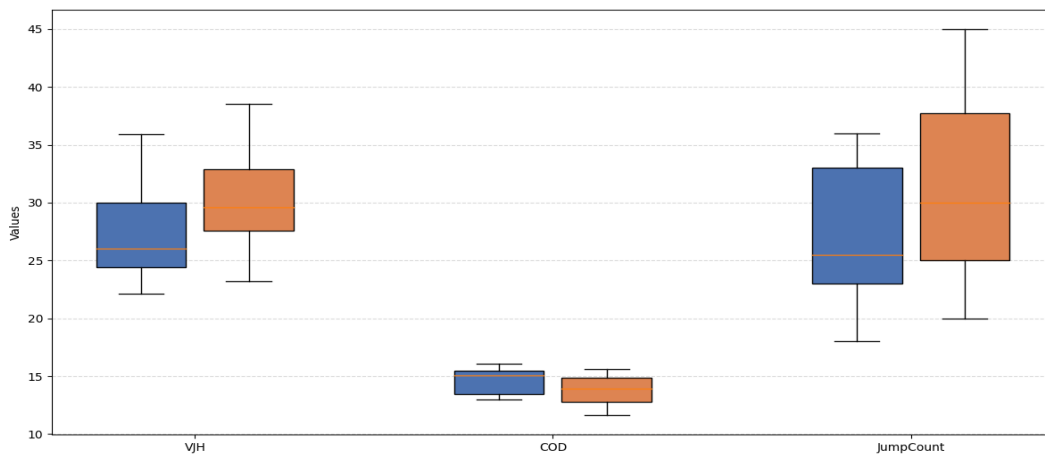


Fig 2. Boxplot for VjH, COD, and JumpCount, initial vs final

Interpretative analysis of performance distributions

Across the five performance variables, the paired comparisons indicate clear pre-post improvements supported by strong statistical indicators. For VJH, the mean increased from 27.07 cm to 30.39 cm, with an average gain of +3.32 cm (+12.36%). The paired comparison produced a t-statistic of -11.81 with a p-value of 1.02×10^{-11} , reflecting a highly consistent upward shift in jump height across athletes. In SP20, mean sprint time decreased from 3.86 s to 3.57 s, an improvement of 0.296 s (+7.64% faster), accompanied by a t-statistic of 14.91 and a p-value of 6.02×10^{-14} , confirming strongly aligned reductions in sprint time. Agility performance measured by COD

also improved, decreasing from 14.67 s to 13.82 s. The mean change of 0.855 s corresponds to a 5.89% improvement, with a t-statistic of 11.07 and p-value of 4.00×10^{-11} , indicating consistent gains in directional speed. The repeated jump ability JC showed a substantial increase from 27.15 to 31.38 repetitions, a gain of +4.23 jumps or +15.25%. The paired comparison returned a t-statistic of -9.74 with a p-value of 5.43×10^{-10} , demonstrating a clear shift toward improved anaerobic power and endurance. For reactive strength, RSI increased from 1.46 to 1.71, an average gain of +0.245 (+16.79%), with a t-statistic of -10.90 and p-value of 5.52×10^{-11} , reinforcing that nearly all participants improved their stretch-shortening cycle efficiency. The direction of all t-statistics (negative for variables increasing, positive for those decreasing) matches the expected direction of functional improvement. *Statistically supported interpretative evaluation of technical football-tennis measures*

The dataset for the four technical football-tennis parameters (table 2 and figure 3) shows a mixed pattern of improvement, with two variables demonstrating statistically meaningful progression and two remaining largely unchanged. For VolleyTotal (VOL_TOT), the improvement is both numerically and statistically robust: the mean increased from 35.12 to 37.42 successful contacts, yielding an average gain of +2.31 repetitions. The paired-samples t-test reflects a strong performance shift ($t = -3.2811$, $p = 0.0030$), indicating that most athletes increased their total number of volleys within the 60-second task. A similar pattern is observed for VolleyBest (VOL_BEST), where the longest rally rose from a mean of 12.35 to 13.15 touches, corresponding to an average improvement of +0.81 repetitions. Although the effect size is modest, the progression is consistent enough to generate a noticeable t-value ($t = -1.7786$) and a borderline p-value ($p = 0.0875$), which—while not conventionally significant—still reflects a directional improvement across the group. In contrast, the Service (SERVICE) parameter shows only a minimal shift, with the mean moving from 66.04% to 66.85%, a difference of merely +0.81%. The corresponding t-statistic is -1.5520, and the p-value is 0.1332, indicating that the variation is too small and inconsistent across participants to suggest meaningful progress. A similar non-significant pattern appears in the Control (CONTROL) variable, where the group mean actually declines slightly from 73.19% to 72.81% (-0.38% on average). The paired-samples t-test confirms the absence of structured improvement ($t = +0.6011$, $p = 0.5532$), with wide intra-individual variability overshadowing any potential training effect. Taken together, these results outline a clear performance profile: the volley-based tasks (VOL_TOT and VOL_BEST) show the most consistent gains, suggesting improved rally stability, coordination, and fine motor control over repeated exchanges. In contrast, the more precision-dependent skills—SERVICE placement and CONTROL accuracy—display negligible group-level improvements, highlighting that accuracy-dominant tasks tend to progress more slowly and require longer-term technical refinement. The combined statistical and numerical evidence thus demonstrates a selective enhancement of certain technical components of football-tennis performance while underscoring the stability or resistance to change of others within the same training interval.

Table 2. Technical Performance Parameters in Football-Tennis – Descriptive Statistics

Variable	Mean Initial	SD Initial	Mean Final	SD Final	Mean Diff	SD Diff
Service (SERVICE)	70.0	10.26	69.46	10.62	-0.54	2.34
VolleyTotal (VOL_TOT)	32.58	6.59	39.69	6.5	7.12	2.36
VolleyBest (VOL_BEST)	12.31	3.07	17.5	2.96	5.19	1.55
Control (CONTROL)	74.81	8.57	74.31	10.24	-0.5	3.0

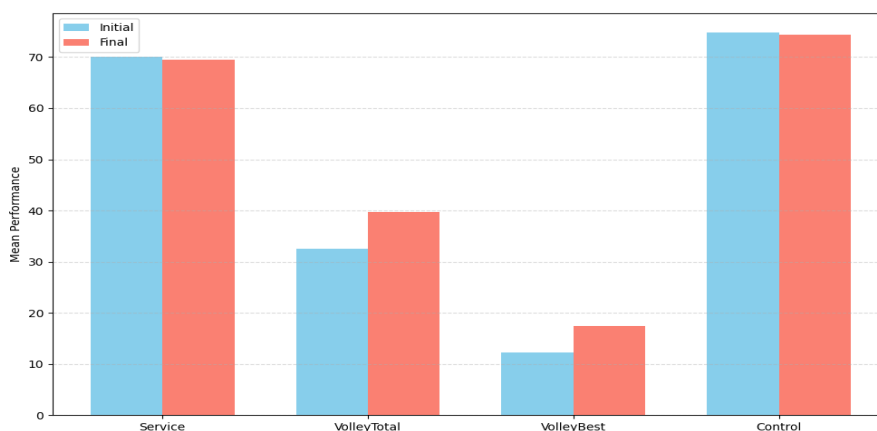


Fig 3. Mean technical performance scores in football-tennis: initial vs final

Discussions

The findings of this study show that an 8-week school-based training program can produce meaningful improvements in physical performance variables—VJH, SP20, COD, JC, and RSI—as well as in several football-tennis technical skills. These results align with evidence that targeted neuromuscular training enhances explosive force and reactive ability, as seen in elite players performing plyometric and sport-specific work (Gherghel et al., 2021). Although our participants were untrained rural middle-school boys, the size of improvements in jump-based measures is comparable to gains observed in structured youth plyometric programs (Ramirez-Campillo et al., 2023). Similar to research linking RSI with sprint and COD performance (Jarvis et al., 2022), our data show parallel advancements across these domains, indicating that stretch-shortening cycle adaptations transfer broadly across explosive tasks. The selective improvement observed in volley-based tasks, compared with precision-oriented skills such as service accuracy, supports the idea that gross neuromuscular adaptations transfer more rapidly to dynamic, repetitive technical actions. Similar findings were reported in youth football and handball contexts, where improvements in strength and coordination did not immediately translate into higher technical precision (Gherman et al., 2024).

Unlike high-performance samples, however, participants showed modest progress in precision-based technical skills, particularly service accuracy and controlled receiving. This pattern corresponds with youth findings showing that technical accuracy relies heavily on underlying motor abilities and develops more slowly than gross motor outputs (Abid Aoun & Katea, 2024). In contrast, stronger gains in volley-related tasks (VOL_TOT, VOL_BEST) likely stem from the repetitive, rhythm-oriented drills, reflecting junior-level evidence that explosive-leg development supports improved ball interaction (Breesim & Majeed, 2024). Compared with match-analysis-based training in competitive youth contexts (Hussain & Khither, 2024), our PE-integrated program involved lower intensity and volume, which may explain the slower progression of fine technical skills.

Physical improvements in sprinting and COD were broadly consistent with elite football-tennis studies emphasizing dynamic footwork and short accelerations (Țifrea et al., 2021), though smaller in magnitude due to the school-adapted training load. Gains in JC and RSI also align with recommendations to use height- and flight-time-derived metrics for tracking neuromuscular adaptation (Anicic et al., 2023). Unlike elite protocols involving high-intensity plyometrics (Gherghel et al., 2021), our moderate-intensity sessions produced incremental but steady improvements, underscoring the feasibility of neuromuscular development in non-athlete youth.

Educationally, the intervention supports evidence that well-structured PE lessons foster meaningful motor development (Slingerland & Borghouts, 2011). Although performance—not behavior—was the study's focus, cooperative and partner-based rally tasks align with pedagogical strategies shown to enhance engagement and task success (Rivera-Pérez et al., 2021). The limited advancement in accuracy-based skills may also reflect the short intervention period, consistent with research indicating that cognitive-technical components require longer or more specialized practice. The importance of objective measurement and technological support in sports performance assessment has been emphasized in recent applied research. Advanced monitoring techniques, including biomechanical and thermal analysis, have been shown to provide valuable insights into training load, fatigue, and movement efficiency in handball and related sports (Șuteu et al., 2025).

Overall, the results indicate that even within time-restricted PE contexts, targeted training can substantially improve core physical capacities and selected sport-specific skills in adolescents. Relative to elite, youth, and school literature, our findings reveal a hybrid pattern: physical variables improved at levels similar to structured athletic programs, while technical accuracy developed more slowly, typical of introductory school-based learning.

Conclusion

The present study demonstrates that an 8-week, school-based football-tennis training program can significantly improve essential physical performance variables—including vertical jump height, sprint speed, change-of-direction ability, jump endurance, and reactive strength—while also producing moderate gains in technical skills such as volley consistency and longest rally. However, improvements in precision-dependent abilities, particularly service accuracy and controlled receiving, were smaller, suggesting that fine motor coordination may require longer or more specialized practice. The study is limited by its relatively small sample size, single-group design, and restriction to male participants from a rural school context, which constrains the generalizability of the findings. Additionally, the absence of long-term follow-up makes it unclear whether the observed gains would persist over time. Future research should incorporate control groups, larger and more diverse samples, and extended intervention periods to better examine developmental trajectories in both physical and technical performance. Longitudinal designs could further clarify how training adaptations evolve across different stages of adolescence. Studies integrating biomechanical technologies, such as wearable sensors, may also enhance precision in monitoring movement quality. From a policy perspective, the findings support

incorporating structured skill-based training modules into physical education curricula to promote motor competence and engagement. Schools in rural or low-resource environments may especially benefit from accessible, field-based training models like the one applied here. Overall, the results highlight the potential of football-tennis as an educational tool that simultaneously develops physical capacities and sport-specific skills in adolescents.

AUTHOR CONTRIBUTIONS

Păuna Răzvan-Dorel, Șerban Rau Tiberiu și Pop Sergiu contributed equally to the design and implementation of the research, to the data collection, analysis and interpretation of the results, and to the writing of the manuscript. All authors had equal rights and responsibilities in the preparation of this work. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest related to this research.

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