ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2026; 33(**2**): 161-170
ISSN 2299-9590
DOI: https://doi.org/10.23829/TSS.2026.33.2-6

Comparative effects of repeated-sprint and plyometric training on aerobic capacity and short-term maximal intensity efforts in youth team-sport athletes

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Abstract

Introduction. Repeated-sprint training (RST) and plyometric jump training (PJT) are key methods in youth conditioning, targeting distinct yet complementary systems – RST enhances metabolic efficiency and fatigue tolerance, whereas PJT develops muscle power and neural activation. Aim of Study. This study aimed to directly compare the effects of RST and PJT on aerobic capacity and short-term maximal intensity performance in youth team-sport athletes. Material and Methods. Thirty-one trained athletes aged 15-17 years participated and were randomly allocated to either the RST or PJT group. Training sessions were conducted three times per week for eight weeks. The RST protocol consisted of short, maximal sprints with limited recovery to stimulate aerobic and anaerobic pathways, whereas the PJT protocol incorporated multi-joint jumping drills to improve explosive strength. Performance measures included aerobic fitness (Yo-Yo Intermittent Recovery Test Level 1 [Yo-Yo IR1]), sprint ability, jump height, lower-body strength, and agility, all of which were assessed before and after the intervention. Results. The RST group showed greater improvements in aerobic capacity and repeated-sprint ability, including a 2.8-unit increase in Yo-Yo IR1 and a 9.8-s reduction in total sprint time. In contrast, the PJT group demonstrated larger gains in jump performance (CMJ +6.1 cm; SJ +6.4 cm) and lower-body strength (+6.0 kg). Performance decrement improved by 7.9% in RST and by 1.8% in PJT, while agility remained unchanged in both groups. Conclusions. Both RST and PJT proved effective but in distinct performance domains. RST predominantly enhanced aerobic and fatigue-related parameters, whereas PJT improved neuromuscular strength and explosive power. Integrating both training modalities within a structured periodization model may optimize the comprehensive development of youth athletes. Future research should address longer training durations, different maturation stages, and sport-specific applications to refine evidence-based conditioning strategies for young players.

KEYWORDS: aerobic capacity, high-intensity performance, plyometric jump training, repeated-sprint.

Received: 20 March 2025
Accepted: 29 December 2025
Published: 30 June 2026

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Introduction

Repeated-sprint training (RST) and plyometric jump training (PJT) are widely recognized as effective strategies for enhancing physical performance in team sports, particularly among young athletes [1, 2]. RST simulates the intermittent high-intensity efforts prevalent in sports such as soccer and basketball, improving repeated-sprint ability (RSA) and fatigue resistance by enhancing the aerobic system's contribution to recovery between efforts [3, 4]. In contrast, PJT targets anaerobic power, speed, and explosive strength through rapid stretch-shortening cycle (SSC) actions, making it a cornerstone for developing jump height and sprint performance [5, 6]. However, controlled experimental studies directly comparing RST and PJT in adolescent athletes are limited in the literature [7, 8]. The growing interest in RST and PJT stems from their ability to address the multifaceted physical demands of team sports. For instance, RST has been shown to enhance RSA and aerobic recovery processes, which are critical for maintaining performance during prolonged, high-intensity match play [9, 10]. This is particularly evident in soccer, where players frequently engage in repeated sprints interspersed with brief recovery periods [4]. Conversely, PJT is highly effective in improving vertical jump height, linear sprint speed, and change-of-direction (CoD) ability, as demonstrated across various sports, including volleyball, basketball, and tennis [6, 11, 12]. Understanding the differential and combined effects of these training methods may help develop effective training programs for youth athletes [13, 14]. Theoretically, distinguishing between neuromuscular and metabolic adaptations provides insight into how these mechanisms evolve during adolescence [15, 16]. In practice, identifying the distinct responses of RST and PJT may help coaches better structure training load and sequence across the phases of athlete development [17, 18]. Furthermore, the transfer effects between these training types, such as PJT's influence on sprint performance or RST's impact on explosive power, highlight their potential interdependence [6, 19].

Although the adaptations to RST and PJT are well documented, controlled studies directly comparing these methods in youth athletes remain limited [3, 20]. This study addresses this gap by investigating the effects of an 8-week RST and PJT intervention on aerobic performance and short-term maximal-intensity efforts in adolescent team-sport athletes aged 15-17. Prior research indicates that RST enhances aerobic recovery processes, whereas PJT primarily promotes neuromuscular and explosive strength adaptations [16, 21]. As one of the few studies directly comparing these modalities, the present study hypothesizes that RST will primarily enhance aerobic capacity and sprint endurance. At the same time, PJT will predominantly improve explosive power and strength. By elucidating their unique and overlapping contributions, this study seeks to provide evidence-based insights to guide coaches and practitioners in designing developmentally appropriate training programs for youth athletes. The selection of performance tests was conceptually guided by the physiological characteristics each was intended to assess. The Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1) was used as a sensitive indicator of aerobic capacity in youth athletes [8, 22], while jump and sprint tests were used to capture anaerobic and neuromuscular adaptations central to sport-specific performance [15, 21]. Beyond practical application, this study contributes conceptually to understanding how distinct training stimuli shape aerobic and anaerobic systems during adolescence. Clarifying these mechanisms supports evidence-based talent identification and long-term athletic development frameworks [7, 17]. Therefore, the central research question of this study was: How do RST and PJT differentially influence aerobic capacity and short-term maximal intensity performance in adolescent team-sport athletes?

Aim of Study

This study aimed to directly compare the effects of RST and PJT on aerobic capacity and short-term maximal intensity performance in youth team-sport athletes.

Material and Methods

Study design

This study utilized a randomized controlled trial design to compare the effects of RST and PJT on aerobic and short-term maximal intensity efforts in adolescent team-sport athletes. Participants were randomly assigned to an RST or PJT group and assessed before and after an 8-week intervention. The primary aim was to evaluate the distinct contributions of RST and PJT to physical performance outcomes in youth athletes, providing insights into their comparative efficacy. This approach enabled direct comparisons between the two training modalities while participants maintained regular sport-specific training.

Participants

A priori power analysis using G*Power software (Version 3.1.9.4, University of Düsseldorf, Germany) determined that a minimum of 12 participants per group was sufficient to detect a medium effect size ($f = 0.25$) with $\alpha = 0.05$ and power $(1 - \beta) = 0.80$, based on the average training effects reported in youth strength and plyometric interventions [23].

Initially, 34 adolescent athletes with at least two years of school team-sport experience (soccer, basketball, or volleyball) were recruited. Three participants were excluded due to health issues or withdrawal, resulting in 31 completing the study (RST: $n = 15$, mean age = 15.27 ± 0.46 years; PJT: $n = 16$, mean age = 15.44 ± 0.51 years). Baseline characteristics showed no significant differences between groups in height (RST: 162.8 ± 7.3 cm, PJT: 160.8 ± 3.5 cm, $p = 0.349$), body mass

(RST: 54.2 ± 8.6 kg, PJT: 53.3 ± 7.3 kg, $p = 0.758$), or progressive maximal endurance shuttle runs (RST: 46.2 ± 1.5 ml/kg/min, PJT: 46.9 ± 1.6 ml/kg/min, $p = 0.213$). Participants trained 3-5 times per week and were classified as "Trained/Developmental" according to McKay et al. [24]. Exclusion criteria included chronic conditions, recent injuries (within 6 months), or supplement use. Informed consent was obtained from participants and their guardians, and the study was approved by the Ethics Committee of the Faculty of Sport Sciences at Atatürk University, in accordance with the Declaration of Helsinki. Participants were instructed to maintain ≥8 hours of sleep and to avoid strenuous activity for 48 hours prior to testing. Although biological maturation was not directly assessed, participants were of similar chronological age (15-17 years) and recruited from comparable developmental stages within school sport programs, minimizing maturity-related variability. Future studies should include objective indicators of maturity status to control for biological growth effects.

Procedures

Participants were randomly assigned to RST or PJT groups using a computer-generated sequence stratified by age. The intervention spanned 8 weeks, with each group completing three 45-minute sessions per week (Monday, Wednesday, and Friday) alongside their regular training. Participants completed the eight-week program in April and May, and all pre- and post-tests were scheduled during this period. A two-week low-intensity anatomical adaptation period preceded the intervention. Pre- and post-tests were conducted 48 hours before and after the intervention, between 14:00 and 17:00, in an indoor facility maintained at 22°C and 45% humidity. All measurement devices were calibrated before each testing session to ensure accuracy. A familiarization session was conducted one week prior to data collection to minimize learning effects and ensure consistent test execution. All measurements were performed by the same experienced investigator to ensure intra-rater reliability across all assessments. A standardized warm-up routine (5 minutes of light jogging followed by 5 minutes of dynamic stretching) was performed before all testing sessions, and the same protocol was applied identically across participants to minimize variability related to neuromuscular readiness. These procedures were implemented to strengthen internal validity and data quality. The RST protocol consisted of 10 × 40-m maximal sprints with 30-s active recovery (jogging) on a flat surface. Participants sprinted from point A to B and back, completing 10 repetitions per session. This protocol was adapted from previous studies on sprint training in team-sport athletes [4, 25]. The PJT protocol included three sets of four drills (4 repetitions per set, 6-min inter-set rest), all performed at maximal effort on a hard surface. The drills were as follows: (1) double-leg jumps over 40-50-cm hurdles followed by a 5-m sprint; (2) lateral double-leg jumps over 40-cm hurdles (2 right, 2 left) with a 5-m sprint; (3) alternating single-leg hops into 1-m-spaced hoops with ≤2-s ground contact; and (4) lateral single-leg hops over 40-cm hurdles (4 right, 4 left) ending with a 5-m sprint [26]. Each session began with a 10-minute warm-up (jogging, dynamic stretching) and ended with a 5-minute cool-down (static stretching) (Table 1).

Measurements

Testing was conducted over three days with 24-hour rest intervals, ensuring consistency in clothing, timing (2 hours post-meal), and environmental conditions. On Day 1, aerobic capacity was assessed using the Yo-Yo IR1, which involves 20-m shuttle runs at increasing speeds with 10-s active recovery (2 × 5-m jog). Total distance covered (m) was recorded as the performance outcome, reflecting intermittent endurance capacity rather than direct maximal oxygen uptake. This measure provides a valid and reliable indicator of aerobic recovery ability in youth athletes [8, 22]. On Day 2, agility was

Table 1. Eight-week RST and PJT program

Weeks	RST	PJT
Adaptation	2-week low-intensity anatomical adaptation	
1-8	10 × 40-m sprint (30-s active recovery/jogging)	Three sets of four drills (4 repetitions per set, 6-min inter-set rest) Drill 1: double-leg jumps (40-50-cm hurdle) + 5-m sprint Drill 2: lateral double-leg jumps (40-cm hurdle, 2 right–2 left) + 5-m sprint Drill 3: alternating single-leg hops into hoops (1-m spacing, ≤2-s ground contact) Drill 4: lateral single-leg hops (40-cm hurdle, 4 right–4 left) + 5-m sprint

Note: PJT – plyometric jump training, RST – repeated-sprint training measured with the 505 test – a 15-m course with a 5-m turn – timed with photocell gates [27]; maximal strength was then evaluated with 10-RM squat and leg press tests, with loads adjusted by 3-10% across three trials with 5-min rests [28]. On Day 3, sprint performance (10 × 40-m with 30-s recovery) was recorded with photocell gates, and jump heights (squat jump [SJ] and countermovement jump [CMJ]) were measured using the My Jump 2 application [29]. Anthropometric data (height: Holtain stadiometer, UK; body mass and fat percentage: Tanita BC-401, Japan) were collected pre-intervention.

Statistical analysis

Data were analyzed using SPSS (Version 21.0, IBM Corp., Armonk, NY, USA). Normality was verified with the Shapiro–Wilk test. Baseline differences between groups were assessed with independent t-tests. Within-group changes were analyzed using paired t-tests. A 2 (time: pre, post) × 2 (group: RST, PJT) ANOVA with repeated measures examined group × time interactions. Sprint performance decrement (% Dec) was calculated as: $[100 \times (\text{total time} \div (\text{best time} \times 10))] - 100$ [30]. Effect sizes were reported as partial η^2 for ANOVA analyses (0.01: small, 0.06: medium, 0.14: large) and Cohen's *d* for t-tests (0.2: small, 0.5: medium, 0.8: large). Significance was set at $p < 0.05$. Test-retest ICCs ranged from 0.88 to 0.96. To strengthen the interpretability of the statistical outcomes, 95% confidence intervals (CI) were computed for all primary variables. Practical significance was additionally evaluated using the smallest worthwhile change (SWC), defined as 0.2 × the between-subject standard deviation. These complementary indices were incorporated to provide a more cautious and contextually meaningful evaluation of the observed changes.

Ethics Committee Report

The decision text from the document titled "2022/2 Faculty Ethics Committee Decisions", reference number E-70400699050.02.04-2200058578, issued during the session held on February 21, 2022, by the Faculty Ethics Committee of the Faculty of Sports Sciences at Atatürk University, is presented below.

Results

As shown in Table 2, following the 8-week intervention, both RST and PJT produced measurable improvements in several performance variables. Significant main effects of time were observed for most outcomes, confirming overall training-related progress in the sample. However, distinct group × time interactions indicated that the two modalities elicited partially different patterns of adaptation. In the Yo-Yo IR1, the RST group demonstrated a larger improvement in total distance compared with the PJT group, indicating a stronger enhancement in intermittent endurance capacity. This finding aligns with the aerobic emphasis of the RST protocol. Regarding neuromuscular performance, PJT

Table 2. Summary of performance changes following RST and PJT

Variable	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Mean change	*p*-value	ηp^2	Interpretation
Yo-Yo IR1 (m)	RST	46.20 ± 1.50	49.00 ± 1.10	+2.80	<0.001	0.721	large improvement
	PJT	46.90 ± 1.60	47.40 ± 1.70	+0.50	0.001	–	minor improvement
CMJ (cm)	RST	34.20 ± 2.70	34.70 ± 3.60	+0.50	0.004	0.700	minimal improvement
	PJT	35.20 ± 3.90	41.30 ± 4.00	+6.10	<0.001	0.772	large improvement
Squat jump (cm)	RST	26.10 ± 4.00	26.80 ± 4.30	+0.70	0.002	0.640	negligible
	PJT	27.60 ± 4.00	34.00 ± 3.10	+6.40	<0.001	0.750	strong improvement
Leg press (kg)	RST	59.10 ± 6.90	61.60 ± 6.50	+2.50	0.003	0.362	moderate increase
	PJT	59.60 ± 6.90	65.60 ± 5.00	+6.00	<0.001	0.780	large improvement
Total sprint time (s)	RST	82.20 ± 4.40	72.40 ± 3.20	−9.80	<0.001	0.622	strong enhancement
	PJT	81.50 ± 3.90	79.00 ± 3.90	−2.50	0.020	–	small improvement
Best sprint time (s)	RST	7.00 ± 0.20	6.60 ± 0.30	−0.40	<0.001	0.401	moderate improvement
	PJT	6.90 ± 0.30	6.80 ± 0.30	−0.10	0.050	–	minimal change

Performance decrement (%)	RST	18.20 ± 3.80	10.30 ± 2.00	−7.90	<0.001	0.425	strong improvement
	PJT	18.20 ± 3.90	16.40 ± 4.00	−1.80	0.050	–	small improvement
Agility (s)	RST	3.40 ± 0.20	3.40 ± 0.20	0.00	0.626	–	no change
	PJT	3.30 ± 0.20	3.30 ± 0.10	0.00	0.356	–	no change

Note: PJT – plyometric jump training, RST – repeated-sprint training
Data are presented as mean ± standard deviation (SD). *p*-values <0.001 are reported as "<0.001" for clarity. Partial η^2 indicates effect size: 0.01 (small), 0.06 (medium), 0.14 (large). All analyses were conducted using a mixed-design ANOVA to evaluate the effects of time (within subjects), group (between subjects), and interaction.

participants exhibited greater increases in CMJ and SJ heights, as well as in leg press strength, reflecting the power-oriented nature of plyometric exercise. RST participants showed smaller gains in these measures. Sprint performance improved in both groups; however, decreases in total and best sprint times, together with a reduction in performance decrement, were more pronounced in the RST group. These results indicate better maintenance of sprint output across repeated efforts. No significant differences in agility performance were found, suggesting that neither training modality had a significant influence on CoD ability under the tested conditions. Overall, both RST and PJT were effective in enhancing selected aspects of athletic performance, although each produced improvements in different physiological domains. RST mainly benefited measures related to aerobic and fatigue-resistance capacity, whereas PJT primarily improved indicators of muscular power.

Figure 1 illustrates the post–pre changes in all performance variables for both training groups, showing that RST resulted in greater improvements in intermittent endurance and repeated sprint performance, whereas PJT produced larger gains in jump height and lower-body strength.

Discussion

This study investigated the comparative effects of an 8-week intervention involving RST and PJT on aerobic and short-term maximal intensity efforts in adolescent team-sport athletes. The results demonstrated that RST significantly enhanced progressive maximal endurance shuttle runs (46.2 to 49.0 ml/kg/min), sprint performance (best sprint: 7.0 to 6.6 s; total sprint:

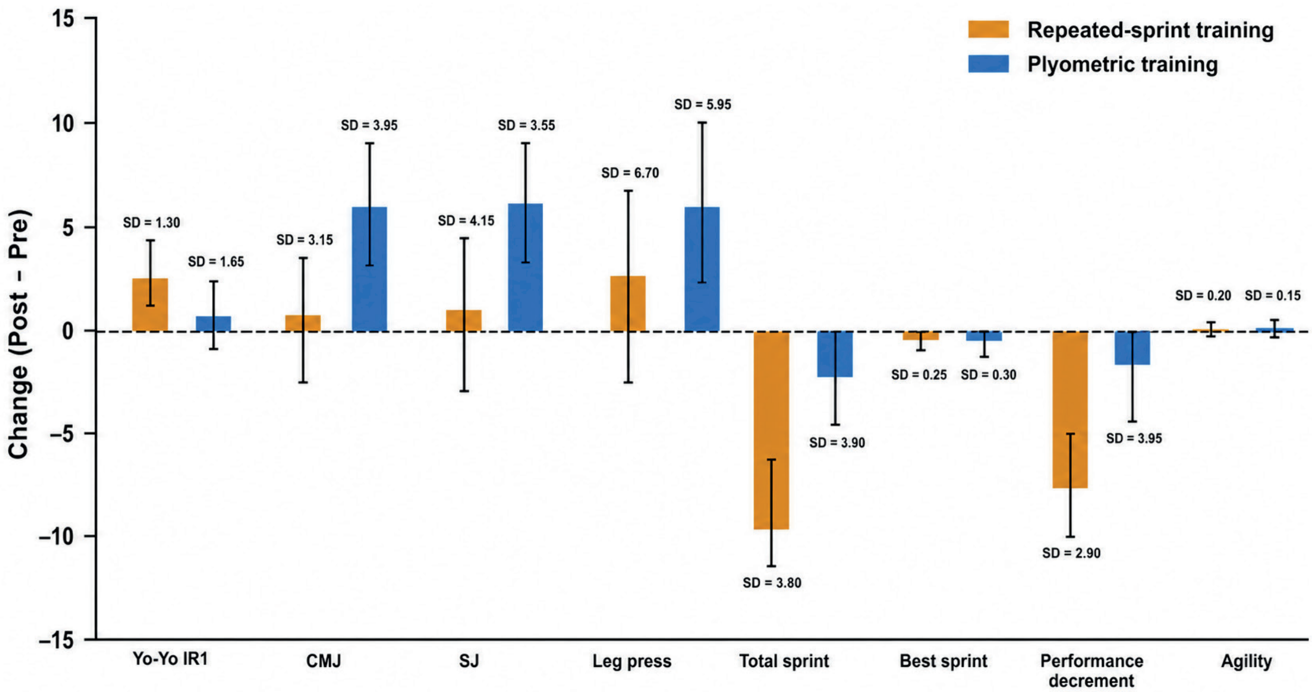

Figure 1. Changes in performance variables following the 8-week training intervention in RST and PJT groups

82.2 to 72.4 s), while PJT elicited more significant improvements in explosive power (SJ: 27.6 to 34.0 cm; CMJ: 35.2 to 41.3 cm) and muscular strength (leg press: 59.6 to 65.6 kg). These findings align with the established roles of RST and PJT as effective strategies for addressing the multifaceted physical demands of team sports, particularly among young athletes [1, 2]. The intermittent structure of RST, which mirrors the needs of sports like soccer and basketball, underscores its utility in enhancing aerobic capacity and RSA [3, 10]. In contrast, PJT's focus on rapid SSC actions bolsters anaerobic power and explosive strength [31]. This investigation contributes to the growing interest in optimizing youth training programs by directly comparing these modalities and revealing their distinct yet complementary adaptations. The observed transfer effects – such as PJT's influence on sprint times and RST's modest strength gains – further suggest potential interdependence between the two modalities, warranting a deeper exploration of their combined application to maximize athletic development [13, 19]. These adaptations are consistent with developmental trajectories observed in adolescent athletes, in which the aerobic and neuromuscular systems mature at different rates [8, 15]. This physiological divergence explains why RST primarily enhances oxygen transport and recovery efficiency, while PJT facilitates improvements in neuromuscular coordination and elastic energy utilization during explosive movements.

The superior enhancement of progressive maximal endurance shuttle runs in the RST group underscores its efficacy in bolstering aerobic capacity, a critical adaptation for team-sport athletes facing repeated high-intensity efforts. This improvement likely stems from RST's intermittent structure, which enhances the aerobic system's contribution to energy production and recovery between sprints [3, 32]. Similar developmental trends in aerobic performance have also been reported [7]. The researchers emphasized that maturation-related differences in cardiac output and hemoglobin concentration can partially explain inter-individual variability in progressive maximal endurance shuttle runs among adolescents. Although biological age was not directly assessed in this study, the narrow age range (15-17 years) likely mitigated major maturational disparities [17]. The protocol's alignment with the Yo-Yo IR1 used in this study may have amplified these cardiovascular benefits by taxing oxidative pathways [9, 32]. Similarly, RST's marked reductions in best sprint time (7.0 to 6.6 s), total sprint time (82.2 to 72.4 s), and performance decrement (18.19% to 10.27%) reflect improved sprint efficiency and fatigue resistance, consistent with its ability to enhance match-like RSA [1, 4]. This aligns with research linking repeated sprints to reduced metabolic fatigue and improved buffering capacity [10, 30]. Comparatively, studies integrating multidirectional sprints with drop jumps report similar sprint and RSA gains, suggesting that RST's benefits may extend beyond linear efforts [33]. In contrast, PJT's minor sprint improvements (best sprint: 6.9 to 6.8 s; total sprint: 81.5 to 79.0 s) indicate a limited direct impact on sprint-specific endurance, aligning with its primary focus on anaerobic power [34]. Research on resisted sprint training further reinforces the sprint-specific superiority of RST, showing more significant acceleration and speed maintenance gains than PJT alone [35]. These findings suggest that the physiological demands of RST, including greater reliance on aerobic metabolism and enhanced recovery capacity, make it particularly suitable for sports requiring sustained high-intensity performance [25, 36].

PJT's pronounced enhancements in countermovement jump and squat jump underscore its superiority in developing explosive power, a hallmark of its reliance on rapid SSC actions. These gains likely arise from improved neuromuscular coordination and increased motor unit recruitment, as PJT's high-velocity contractions enhance elastic energy utilization and force production [2, 5]. Research on PJT direction further supports this, demonstrating that combined vertical and horizontal actions – similar to our protocol – yield greater power improvements than single-direction efforts [37]. Similarly, PJT's superior leg press strength gains compared to RST reflect its emphasis on eccentric loading, which stimulates muscle hypertrophy and maximal force capacity more effectively [31, 38]. In contrast, RST showed minimal jump improvements (CMJ: 34.2 to 34.7 cm; SJ: 26.1 to 26.8 cm) and smaller strength gains (leg press: 59.1 to 61.6 kg), aligning with its focus on speed and endurance rather than power development [19, 34]. The differential effects highlight PJT's specificity for anaerobic power, contrasting with RST's aerobic and sprint-focused adaptations [5, 12]. This specificity suggests that PJT is particularly suited to sports that demand vertical explosiveness, such as volleyball or basketball, where rapid force generation is paramount [11]. However, unlike previous studies reporting moderate aerobic cross-adaptations following plyometric interventions [15, 21], the present results indicate that such transfer effects were minimal. This contrast may reflect differences in protocol jump frequency, recovery duration, or participant developmental stage, reinforcing the need for age- and load-specific plyometric prescriptions.

The lack of substantial improvement in agility following both RST (3.4 to 3.4 s) and PJT (3.3 to 3.3 s) suggests that neither training modality significantly enhanced agility performance. This outcome may be related to the characteristics of the 505 agility test, which primarily emphasizes linear speed and a single change of direction [36]. PJT's emphasis on vertical power over lateral movement likely contributed to its limited effect [24]. RST's focus on linear sprinting failed to address the rapid directional changes required in agility tasks [10]. This absence of agility improvement could also stem from the testing procedure itself, which primarily captures linear acceleration rather than multi-directional or reactive agility. Previous longitudinal observations in youth athletes [18] have shown that direction-change ability develops later and is more sensitive to neuromuscular maturity than to isolated speed or power training. These modest agility gains highlight the need to incorporate sport-specific agility drills tailored to athletes' sport demands. However, combining RST and PJT may enhance CoD and jump performance, as demonstrated by studies incorporating multidirectional sprints [33]. These findings have practical implications for youth training programs: RST is particularly suited for sports like soccer, where sprint endurance and aerobic capacity are critical [35], while PJT excels in power-focused sports such as volleyball, aligning with its strength in enhancing explosive power [37]. Integrating RST and PJT, as supported by integrated protocols, could optimize overall performance by addressing both aerobic and anaerobic demands, and innovations such as blood flow restriction or neuromuscular electrical stimulation may further enhance these gains without increasing training volume. However, their application requires further investigation [33, 38, 39].

From the perspective of long-term athlete development, RST and PJT provide complementary contributions at different stages of youth athletic progression. During the early developmental and fundamental training phases, PJT plays a critical role in enhancing neuromuscular coordination, motor skill acquisition, and explosive power, thereby establishing the foundation for future athletic performance. In contrast, during adolescence and competitive phases, RST contributes to the maintenance of high-intensity performance by improving aerobic capacity, sprint endurance, and fatigue resistance. Accordingly, implementing these methods in an age- and development-appropriate manner can ensure not only short-term performance gains but also sustainable improvements over time. From a periodization standpoint, prioritizing PJT during preparatory and pre-competitive phases, while emphasizing RST during preparatory and competitive phases, may maximize physiological adaptations and reduce injury risk. Ultimately, strategically sequencing RST and PJT within long-term development frameworks can foster balanced, sustainable improvements in the physical, physiological, and technical capacities of youth athletes.

Limitations of this study include the lack of a control group, which may limit the ability to isolate maturation effects, and a restricted sample composition. While this study provides meaningful insights into the comparative effects of RST and PJT on aerobic and short-term maximal intensity efforts in youth team-sport athletes, several limitations should be acknowledged. The relatively small sample size (n = 31) limited the statistical power of the repeated-measures analyses, particularly for detecting interaction effects among multiple performance variables, and therefore restricts the generalizability of the findings to wider athletic populations. Participant recruitment was based on convenience sampling of school-level athletes rather than random or stratified selection, which may have introduced sampling bias and reduced external validity. Although intra-rater reliability was maintained by having all measurements conducted by the same investigator, the absence of reported inter-rater reliability and calibration procedures may limit confidence in the data's precision. Furthermore, the eight-week training duration, while sufficient to elicit short-term adaptations, may not have been long enough to capture chronic physiological and neuromuscular changes, particularly those influenced by maturation. The absence of a control group also prevents clear differentiation between training-induced improvements and natural developmental progression during adolescence. Future studies should incorporate control groups, larger and more diverse samples, and extended intervention periods to confirm these findings and better isolate the specific contributions of RST and PJT. Despite these limitations, the present study provides valuable experimental evidence demonstrating that both training modalities elicit distinct yet complementary adaptations, which can inform evidence-based programming for the long-term development of youth athletes.

The findings of this study suggest that RST and PJT can be strategically implemented according to sport-specific demands in youth athletes. Coaches working in endurance- and sprint-oriented team sports should prioritize RST to improve aerobic capacity, sprint endurance, and fatigue resistance. In contrast, PJT should be emphasized in sports that rely on explosive power and jumping ability. Integrating both modalities within a structured periodization framework may promote balanced development of aerobic and anaerobic systems. Future studies should examine the combined and long-term effects of RST and PJT across different maturation stages to refine evidence-based training strategies for adolescent athletes. Moreover, maturational variation during adolescence can differentially affect aerobic and anaerobic adaptations. Future studies should therefore incorporate maturity offset or skeletal age assessments to control for this confounding factor. Overall, by contrasting two functionally distinct modalities within a homogeneous adolescent sample, this study advances current understanding of how aerobic and neuromuscular systems co-develop during late puberty. These insights contribute to refining age-appropriate conditioning strategies that align with long-term athlete development models and with an athlete's physiological potential.

Conclusions

This study demonstrates that RST and PJT induce distinct yet complementary adaptations in adolescent athletes. While RST enhances aerobic endurance, anaerobic capacity, and sprint performance, PJT significantly improves explosive power, jump height, and lower-extremity strength. It is recommended that training programs be designed according to the sport-specific demands. Future research should focus on determining the most effective ways to integrate these two methods and examining factors such as training periodization, sequencing, and physiological adaptations in young athletes. These interpretations were supported by additional analyses using CIs and SWC to ensure a cautious evaluation of the practical relevance of the findings.

Funding

No external funding.

Conflict of Interest

The authors declare no conflict of interest.

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