

Research article

Influence of Repeated-Sprint Bout Duration in Sprint Interval Training Intervention on Physical Performance Adaptations of Young Volleyball Players

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Abstract

The objective of this study was to examine the effects of repeated-sprint training (RST) with varying bout durations on the physical fitness adaptations of young male volleyball players. Forty athletes were randomly allocated to one of three intervention groups performing RST with varying bout durations and similar repetition volumes, all executed at maximal effort. The 3-sec group ($n = 10$) completed two sets of 30 bouts, the 6-sec group ($n = 10$) performed two sets of 15 bouts, and the 9-sec group ($n = 10$) carried out two sets of 10 bouts, each adhering to a 1:3 work to rest ratio. An active control group ($n = 10$) engaged solely in regular volleyball training without the RST intervention. Physical fitness measures-including countermovement vertical jump (CMVJ), 10-m and 20-m linear sprints, T-test change-of-direction speed (T-CODS), reactive strength index (RSI), and the Wingate anaerobic power test-were assessed pre- and post-a 6-week training intervention (i.e., 18 sessions). All RST groups showed significant post-intervention improvements in physical fitness (main effect of time, $p = 0.001$), with greater adaptations compared with the control group and effect sizes ranging from small to very large. The 3-sec bout group demonstrated greater gains in CMVJ, 10-m and 20-m sprint performance, RSI, and peak power output compared with the 9-sec group (all, $p < 0.05$). Conversely, the 9-sec group exhibited superior adaptations in T-CODS and mean power output relative to the 3-sec group (all, $p < 0.05$). In conclusion, the 3-sec group experienced greater enhancements in explosive and sprint performances, while the 9-sec group showed superior gains in change of direction and mean power output. These findings indicate that manipulation of sprint-bout duration in RST can be used to optimize distinct performance adaptations in young volleyball players.

Key words: Repeated sprint training, power, metabolic conditioning, anaerobic capacity.

Introduction

Volleyball is a team sport that is characterized by short, intense activity bursts, usually lasting from 3 to 9 sec, followed by longer recovery intervals of low to moderate intensity, which can last between 10 and 20 sec (Sheppard et al., 2007). During a volleyball match, players undertake various maximal effort trials, including spike and block jumps, as well as movements in linear directions (Wells, 2011; Reeser and Bahr, 2017). Therefore, players must demonstrate anaerobic performance to generate maximum power over very short durations, particularly during directional changes and jumping tasks (Silva et al., 2019). As a result, the physical fitness and power of each player is vital

for achieving optimal performance in a match (Lakhdar and Zerf, 2019).

Plyometric training is widely used to enhance neuromuscular and explosive performance characteristics relevant to volleyball, such as jumping and sprinting ability (Silva et al., 2019; Ramirez-Campillo et al., 2020; Ning and Sheykhlovand, 2025). However, the high volume of repeated jump landings inherent to both volleyball practice and plyometric training has been associated with an increased risk of overuse injuries, including patellofemoral pain and ankle sprains (Boeth et al., 2017). Consequently, there is growing interest in complementary or alternative training modalities that may elicit comparable performance adaptations while potentially reducing cumulative mechanical loading (Girard et al., 2011). In this context, recent studies suggest that repeated sprint training (RST) represents a promising and time-efficient training approach for improving selected physical performance outcomes including jumping and sprinting abilities and anaerobic power outputs in volleyball players (Wei et al., 2025; Guo and Wang, 2024; Tao et al., 2024). Evidence indicates that 6 - 8 weeks of RST, using different sprint bout durations, can improve sprint speed, explosive power, and repeated-sprint capacity in volleyball players, aligning with the sport-specific requirements of frequent accelerations and jumps (Fang and Jiang, 2024; Boullosa et al., 2022; Dolci et al., 2020; Arazi et al., 2017; Li and Sheykhlovand, 2025). According to Tao et al., (2024), RST elicited improvements in sprint speed, explosive jump performance, change of direction ability and anaerobic power performance, as well as cardiorespiratory fitness in female volleyball players.

According to Boullosa et al., (2022), RST protocols employing short sprint bout durations (< 10 sec), compared with longer bouts (> 10 sec), predominantly stress the ATP-PCr energy system, induce lower glycolytic contribution, and result in reduced peripheral fatigue and perceived exertion. These characteristics make short-duration RST particularly effective for maintaining high neuromuscular output across repetitions (Boullosa et al., 2022; Tao et al., 2024). Nevertheless, sprint performance demands are sport-specific, and not all team sports rely on identical energetic and mechanical profiles (Laursen and Buchheit, 2019). Longer sprint bout durations (> 10 sec) progressively increase glycolytic involvement and metabolic stress, which may be more relevant for sports or playing positions requiring prolonged high-intensity efforts. Therefore, tailoring RST bout duration is essential to align the dominant energy pathway stimulation (ATP-PCr vs. glyco-

lytic) with the specific physiological and performance requirements of the target sport (Laursen and Buchheit, 2019). Recently, Rey et al., (2024) reported greater sprint performance improvements following 40-m (~6-sec) compared with 20-m (~3-sec) RST in male soccer players; however, these adaptations primarily reflect enhancements in repeated-sprint ability rather than maximal sprint speed, which typically requires longer recovery durations (e.g., sprint interval training).

Given that volleyball-specific high-intensity efforts typically last 3 - 9 sec (Sheppard et al., 2007), RST bout duration should be selected to reflect these temporal demands. Although no studies have directly examined the optimal RST bout duration in volleyball players, research in other team sports, particularly soccer, indicates that manipulating sprint bout duration can differentially influence physical performance adaptations (e.g., Rey et al., 2024; Boullosa et al., 2022). Given the distinct movement patterns and temporal demands of volleyball, sport-specific evidence is still required. Therefore, this study aimed to investigate the effects of three RST bout durations (3, 6, and 9 sec) performed under all-out conditions on the physical performance adaptations of young male volleyball players.

Methods

Study design

A randomized controlled approach with pre and post-testing was utilized to evaluate the intervention effects. The experimental design included three interventions and one active control group over an eight-week period. The protocol progressed through a baseline testing week (Week 1), a six-week training phase (Week 2 to 7), and a final week of follow-up assessments (Week 8), within the period of October to December 2024. Participants engaged in various physical fitness evaluations, such as the countermovement vertical jump (CMVJ), 10-m and 20-m linear sprints, T-test change of direction speed (T-CODS), reactive strength index (RSI) derived from a drop-jump test, and the Wingate anaerobic power test. To minimize fatigue and avoid interference effects between tests, assessments were divided into two sessions separated by a 48-h recovery interval. Following anthropometric assessments, participants completed the CMVJ, linear sprint, and T-CODS on Day 1, with 10-min rest intervals between tests. On Day 2 (48 h later), participants performed the drop-jump test for RSI and the Wingate anaerobic power test, separated by a 10-min recovery period. All players participated in volleyball training sessions scheduled for Monday, Wednesday, and Friday. On these days, the experimental groups performed RST immediately before their volleyball training sessions. To control for the possible effects of circadian variation, all physical assessments and RST sessions were conducted in alignment with the team's standard training schedule between 4:00 p.m. and 6:00 p.m., when technical and tactical activities traditionally occurred. Although all physical performance assessments were conducted on an indoor wooden volleyball court, the RST sessions were performed in a straight, unobstructed indoor corridor adjacent to the volleyball facility, allowing athletes to complete the prescribed sprint distances (25 m, 45 m, and 75 m) as contin-

uous linear efforts without changes of direction. The identical testing sequence used before the intervention was repeated at the conclusion of the six-week program for post-test evaluation.

Participants

The study involved forty young male amateur volleyball players (Tier 1; McKay et al., 2022) who volunteered to participate. Participants were matched by playing position and then randomly allocated to one of four groups: three RST groups or an active control (CON) group (Table 1). To determine the necessary sample size, G*Power software (version 3.1) was utilized, applying the statistical test of "ANOVA/repeated measures/within-between interaction." The analysis parameters included an anticipated effect size (f) of 0.25, a significance level (α) of 0.05, a desired statistical power of 0.90, a correlation coefficient of 0.5, four groups, and two measurements, which indicated that a total sample size of $n = 32$ was required (Tao et al., 2024). To account for the possibility of participant withdrawal or incomplete datasets, the study enlisted forty male volleyball players. Random allocation to study groups was executed in a 1:1:1:1 ratio through a computer-based sequence generated in R (version 2.14; R Foundation for Statistical Computing) to ensure impartial distribution. All participants were drawn from a single local volleyball academy and engaged in standardized training loads and schedules, comprising tactical and technical drills held thrice weekly, with each session lasting 70 - 90 min. This routine was maintained consistently before and throughout the investigation. Eligibility required that participants: (a) had no history of lower-limb injury (Gharaat et al., 2025); (b) had no current musculoskeletal, neurological, or orthopedic disorders that could limit participation; (c) had not consumed nutritional supplements for at least six months prior to the study and refrained from supplement or prescribed medication use throughout the experimental period, as verified by self-report and researcher monitoring; (d) had a minimum of two years of formal volleyball training experience; and (e) were between 18 and 20 years of age. To verify adherence to these criteria, a health history questionnaire was distributed, and all participants underwent screening by a sports medicine physician. Prior to the initiation of the study, participants received a comprehensive overview of the research protocols, including the requirements, potential benefits, and associated risks, and subsequently provided their written consent. The study's design received approval from the Ethics Committee of Henan University of Technology (Code 2024/GG12874), in accordance with the Declaration of Helsinki.

Table 1. Participants' characteristics.

Variables	Groups			
	3-sec	6-sec	9-sec	CON
Age (y)	19.2 ± 0.8	19.5 ± 0.4	19.1 ± 0.9	19.5 ± 0.6
Height (m)	1.84 ± 0.07	1.86 ± 0.05	1.88 ± 0.07	1.86 ± 0.06
Body mass (kg)	79.8 ± 6.4	80.4 ± 7.3	79.5 ± 6.8	81.1 ± 5.5

Procedure

Throughout the intervention, athletes were instructed to maintain their habitual lifestyle and dietary patterns. Be-

for each testing session, participants completed a standardized 20-min warm-up composed of 10 min of light jogging, 5 min of dynamic stretching, and 5 min of submaximal sprints. All evaluations were performed on an indoor wooden volleyball court under controlled environmental conditions (27 - 29 °C) during the afternoon hours (16:00 - 18:00). To reduce measurement bias, assessments were conducted by certified strength and conditioning coaches who were blinded to group allocation.

Anthropometric measurements

The height of the participants was assessed using a wall-mounted stadiometer (± 0.5 cm, Seca 222, Terre Haute, IN). A digital scale (± 0.1 kg, Tanita, Japan) was employed to measure the body mass of the participants. To ensure accuracy, all measurements were taken twice and the best score was recorded.

CMVJ measurement

The VERTEC device (Knoxville, Tennessee), was utilized to assess vertical jump height during the CMVJ test. A one-handed reach was conducted to measure the maximum displacement of vanes from a flat-footed, standing position. Following the verbal cue "GO," participants flexed their knees to about 90 degrees, using an elastic band aligned with the floor, and jumped to achieve their maximum height. The vertical jump performance was evaluated by calculating the difference in vane displacement between the jump and the standing reach. Participants executed three maximal jumps, with a minimum recovery period of thirty seconds between each jump and the highest score achieved was selected for statistical evaluation. The reliability coefficient (ICC) for repeated CMVJ measurements was 0.95, as previously reported by Guo and Wang (2024) using the same methodology.

Linear sprint measurement

Linear sprint performance was assessed over 20 m, with split times recorded at 10 m using a telemetric photocell timing system (Witty System; Microgate, Bolzano, Italy). A single-beam photocell configuration was used, with gates positioned 0.3 m above ground level at the start line, 10 m, and 20 m. The reduced height was selected to ensure beam interruption by the athlete's lower limbs during the initial acceleration phase and to minimize premature triggering by arm movements. Participants began each sprint from a standing split stance, with the lead foot placed 0.3 m behind the first gate. Three maximal trials were performed, each separated by a 3-min passive recovery period, and the fastest time was used for analysis. According to Song and Deng (2023), who used the same methodological approach, the ICCs for the 10-m and 20-m sprint splits were 0.93 and 0.94, respectively.

T-CODS measurement

This test was utilized to evaluate the speed related to directional changes, encompassing forward sprinting, lateral shuffling to the left and right, and backpedaling, as previously detailed by Miller et al. (2006). Each participant performed three attempts, with a 2-minute rest period, and the quickest time was chosen for subsequent analysis. The ICC

for repeated measurements during the T-CODS was 0.93 (Miller et al., 2006). Using the same methodology, the ICC for repeated T-CODS measurements was 0.93, as previously reported by Miller et al. (2006).

RSI measurement

Participants performed depth jumps from a 45-cm platform using an electronic contact mat system (Globus Tester, Codognè, Italy). RSI was calculated as jump height divided by ground contact time ($\text{m}\cdot\text{s}^{-1}$), with the system providing temporal resolution to 0.01 s, as previously described (Wallace et al., 2010). They were instructed to keep their hands on their hips, step off the platform with the leading leg extended, and ensure a drop height of 45 cm by refraining from any initial upward movement. The aim was to achieve maximal jump height while minimizing ground contact time to enhance reactive strength. Each participant completed three depth-jump trials with 15 s passive recovery, and the trial producing the highest RSI was retained for analysis. RSI was calculated as jump height divided by ground contact time ($\text{m}\cdot\text{s}^{-1}$). As reported by Pleša et al. (2022), who used the same methodology, the ICC for the RSI was 0.97.

Wingate anaerobic power test

The anaerobic power test was conducted using a cycle ergometer (Ergometrics 874, Monark, Sweden). Following a 5-minute warm-up, participants were directed to pedal at maximum speed for a 30-sec against a resistance calculated by multiplying their body mass in kilograms by 0.075. The peak power was determined by averaging the power output over a 5-second interval, typically observed during the initial 5 seconds of the test. The mean power was derived from the average power output throughout the entire 30-second duration (Nikolaidis et al., 2016).

Training intervention

Participants maintained their regular volleyball training, consisting of tactical exercises, technical drills, and practice matches. Every session commenced with a 20-minute warm-up consisting of 10 minutes of running, 5 minutes of stretching, and 5 minutes of sprinting and ballistic movements. The active CON group only continued with their typical volleyball training routine, while the training groups engaged in the RST intervention with similar training volume-load (Table 2). Prior to the volleyball training sessions, the training groups engaged in RST programs with a 3-minute rest interval between sets. The trials varied in duration, including all-out conditions of 3 seconds, 6 seconds, or 9 seconds (Buchheit and Laursen, 2013; Boullosa et al., 2022; Rey et al., 2024). The players performed the RST program using a fixed work-to-rest ratio of 1:3 (passive recovery including walking) to standardize recovery relative to sprint duration (Laursen and Buchheit, 2019; Buchheit and Laursen, 2013; Boullosa et al., 2022; Rey et al., 2024). The RST program for the training groups required participants to perform linear sprints of varying distances: 25 m for the 3-sec group, 45 m for the 6-sec group, and 75 m for the 9-sec group. These distances were selected to correspond to the average distance covered by the players during maximal sprinting efforts lasting 3, 6,

and 9 seconds, respectively. Distance-time relationships were estimated based on preliminary sprint testing and the known sprint velocities of trained volleyball players, ensuring that each sprint bout duration accurately reflected the intended temporal demands. All sprints were performed from a stationary standing start position. Two auditory cues were employed during training: the first signaled the initiation of maximal-effort sprinting, and the second indicated its termination and the commencement of self-paced walking or running recovery. Athletes were instructed to perform each sprint at maximal velocity, in accordance with the protocol described by Tao et al. (2024). Sessions were monitored by a certified strength and conditioning coach at a supervision ratio of 1 coach per 5 players, ensuring proper technique and adherence to protocols.

Table 2. Repeated sprint interval training program.

Training program elements	Groups		
	3-sec	6-sec	9-sec
Bout duration	3 seconds	6 seconds	9 seconds
Recovery ratio (1 [bout]: 3 [rest])	9 seconds	18 seconds	27 seconds
Repetitions (set/ reps)	2/30	2/15	2/10
Rest between sets (sec)	180	180	180
Total bout durations (sec)	180	180	180

Statistical analysis

The data were expressed as mean \pm standard deviation (SD). The normality of the data was confirmed using the Shapiro-Wilk test for both pre-test and post-test values, while Levene's test verified the homogeneity of variances, with no significant violations observed ($p > 0.05$). A repeated-measures analysis of variance (ANOVA) with a two-factor design (time [2] \times group [4]) was performed, followed by a Bonferroni post-hoc test to identify differences among groups with aiming to control Type 1 error. The effect size (ES) was calculated with a 95% confidence interval (CI) to assess the magnitude of training effects. Hedge's g was used to compute the ES for all measures. Based on the classification established by Hopkins et al. (2009), an ES of < 0.2 was deemed trivial, $0.2 - 0.6$ was

small, $0.6 - 1.2$ was moderate, $1.2 - 2.0$ was large, $2.0 - 4.0$ was very large, and > 4.0 was considered nearly perfect. In addition, the percent change ($\Delta\%$) from pre- to post-training was determined for each variable ($\Delta\% = \text{post-test} - \text{pre-test} / \text{pre-test} \times 100$). Moreover, the one-way ANOVA was used to determine the differences among the groups in the $\Delta\%$ and the Bonferroni post-hoc test was employed for pairwise comparisons.

In addition, between-group differences were quantified using the standardized mean difference (SMD). SMDs were calculated as the difference in post-intervention mean values between groups divided by the pooled standard deviation. The significance threshold was set at 0.05. The analysis of the data was conducted using SPSS software (Version 24, SPSS Institute in Chicago, IL, USA).

Results

All participants fully complied with the experimental procedures, yielding complete protocol adherence. No test- or training-related injuries occurred throughout the study. Baseline analyses indicated no statistically significant differences between groups ($p > 0.05$).

Within-group changes

Following the 6-week intervention, all RST groups demonstrated significant pre-to-post improvements (all, $p < 0.05$) with small to very large ESs across CMVJ, linear sprint performance (10- and 20-m), T-CODS, RSI, peak power, and mean power (Figure 1, Figure 2, Figure 3, Figure 4, and Figure 5).

In contrast, the CON group showed no significant changes, with trivial ESs across all measured outcomes.

Group \times time interaction effects

A significant group \times time interaction was observed for all performance variables (all $p \leq 0.001$), indicating differential adaptations among the training groups and CON group (Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5).

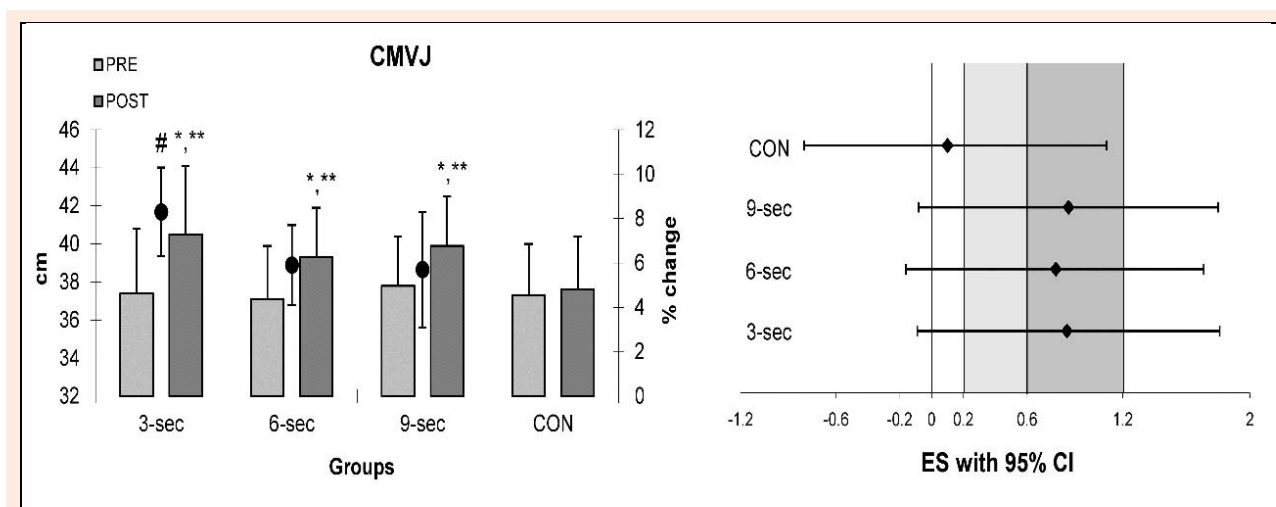


Figure 1. Pre to post-intervention changes in the CMVJ (mean \pm SD) and ES with 95% CI. * Significant differences compared with Pre ($p < 0.05$). ** Significant differences compared with CON group ($p < 0.05$). # Significant differences compared with 9-sec group ($p < 0.05$).

Post-hoc analyses revealed that the 3-sec RST group demonstrated greater improvements than the 9-sec group in CMVJ ($p = 0.039$; $SMD = 0.19$, 95% CI = -0.70 to 1.06), 10-m sprint ($p = 0.010$; $SMD = -0.69$, 95% CI = -1.56 to 0.24), 20-m sprint ($p = 0.025$; $SMD = -0.23$, 95% CI = -1.10 to 0.66), RSI ($p = 0.001$; $SMD = 0.12$, 95% CI = -0.76 to 1.00), and peak power output ($p = 0.050$; $SMD = 0.42$, 95% CI = -0.48 to 1.29). In addition, the 6-sec group showed greater gains than the 9-sec group in RSI ($p = 0.027$; $SMD = 0.16$, 95% CI = -0.73 to 1.03).

Conversely, the 9-sec group exhibited superior adaptations in T-CODS compared with the 3-sec group ($p = 0.018$; $SMD = -0.87$, 95% CI = -1.74 to 0.08) and greater improvements in mean power output compared with both the 3-sec ($p = 0.001$; $SMD = 0.27$, 95% CI = -0.61 to 1.15) and 6-sec ($p = 0.004$; $SMD = 0.31$, 95% CI = -0.59 to 1.17)

groups.

Discussion

Recent studies have examined the effects of repeated-sprint and high-intensity interval training on volleyball players' performance (Guo and Wang, 2024; Tao et al., 2024; Wei et al., 2025). However, the extent to which the duration of intervals within RST sessions modulates physical performance adaptations remains unclear. The present study sought to assess how manipulating bout durations during RST impacts key performance variables in young volleyball players. Our findings indicate that while all RST protocols elicited improvements in power, sprinting, and change-of-direction abilities, the magnitude and specificity of adaptations depended strongly on the duration of sprint-interval bouts.

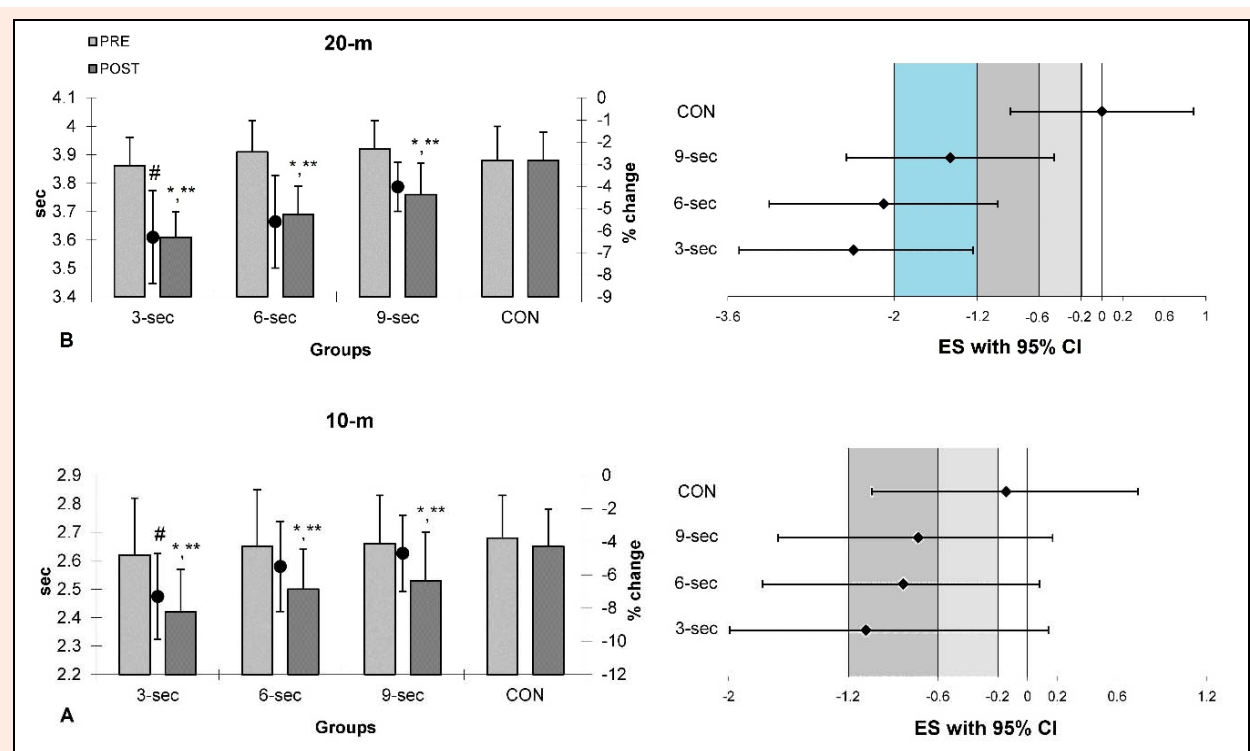


Figure 2. Pre to post-intervention changes in the 10-m (A) and 20-m (B) sprint times (mean \pm SD) and ES with 95% CI. * Significant differences compared with Pre ($p < 0.05$). ** Significant differences compared with CON group ($p < 0.05$). # Significant differences compared with 9-sec group ($p < 0.05$).

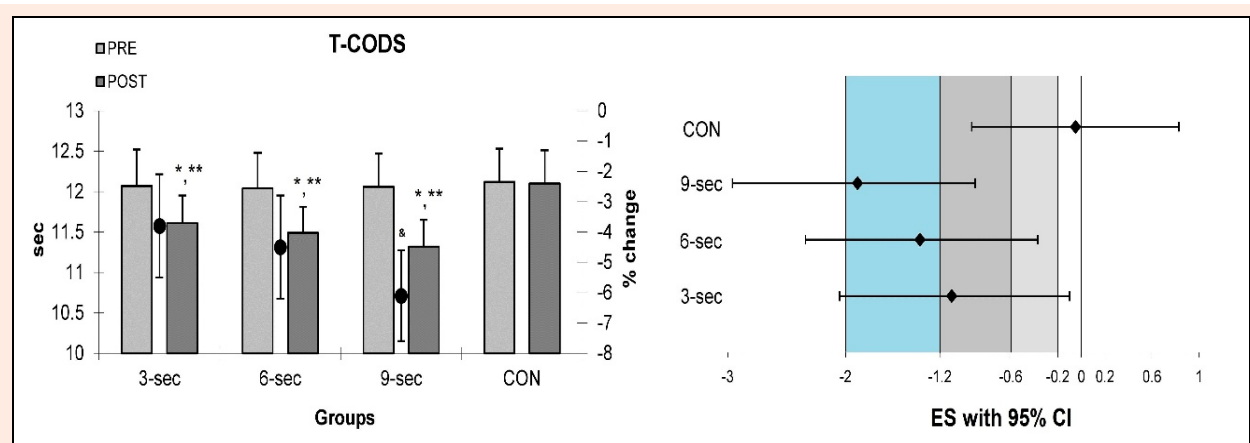


Figure 3. Pre to post-intervention changes in the T-CODS (mean \pm SD) and ES with 95% CI. * Significant differences compared with Pre ($p < 0.05$). ** Significant differences compared with CON group ($p < 0.05$). & Significant differences compared with 3-sec group ($p < 0.05$).

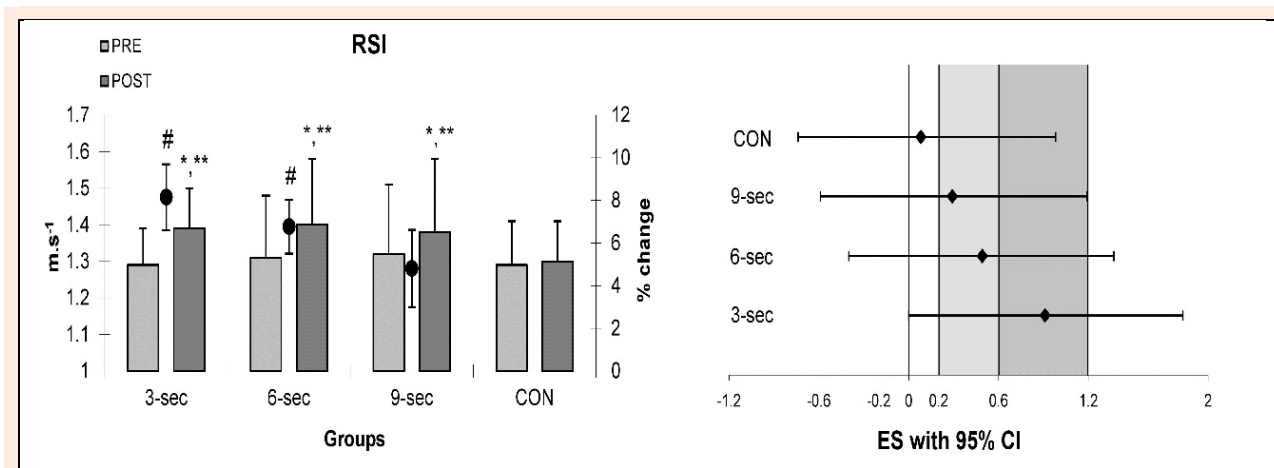


Figure 4. Pre to post-intervention changes in the RSI (mean ± SD) and ES with 95% CI. * Significant differences compared with Pre ($p < 0.05$). ** Significant differences compared with CON group ($p < 0.05$). # Significant differences compared with 3-sec group ($p < 0.05$).

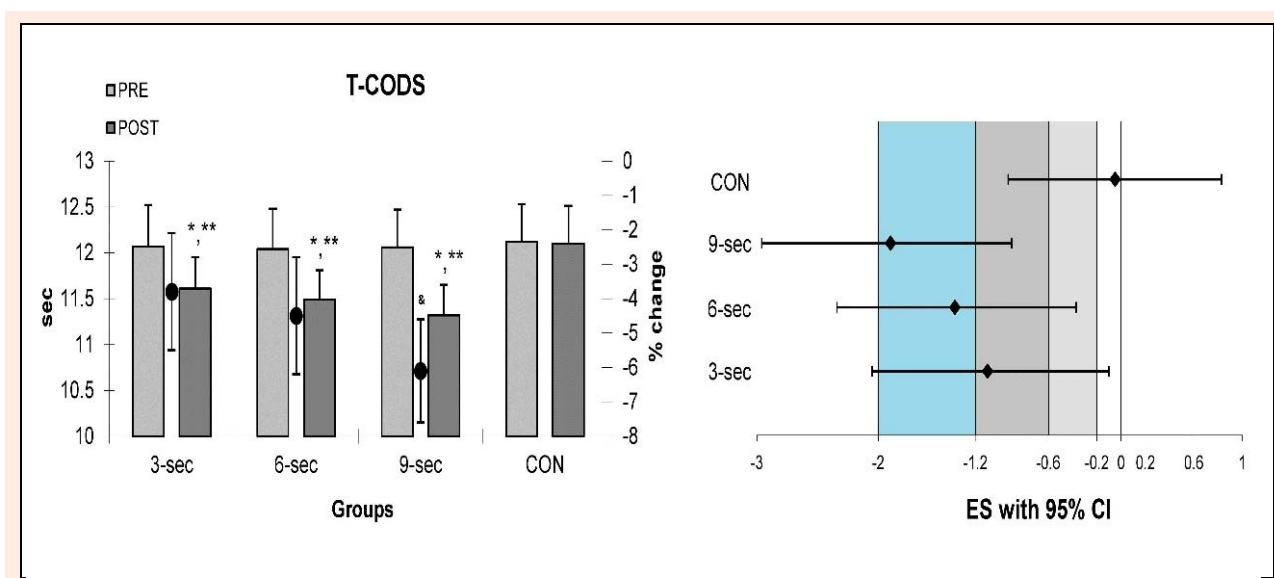


Figure 5. Pre to post-intervention changes in the peak power (A) and mean power (B) outputs (mean ± SD) and ES with 95% CI. * Significant differences compared with Pre ($p < 0.05$). ** Significant differences compared with CON group ($p < 0.05$). # Significant differences compared with 9-sec group ($p < 0.05$). & Significant differences compared with 3-sec group ($p < 0.05$).

Consistent with previous research on the benefits of RST for physical development in volleyball players (Guo and Wang, 2024; Tao et al., 2024; Wei et al., 2025), our data indicate that all intervention groups achieved significant improvements in CMVJ, sprint performance, T-CODS, RSI, and Wingate-derived power outputs following the 6-week intervention, with ESs ranging from small to very large. Gains in explosive and change-of-direction performance likely reflect neuromuscular adaptations induced by repeated exposure to high-intensity actions, including enhanced motor-unit recruitment and firing synchronization (Kunz et al., 2019). In contrast, improvements in 30-s Wingate mean power may be more strongly associated with enhanced anaerobic glycolytic capacity and an improved ability to sustain power output during repeated maximal efforts under fatigue (Kunz et al., 2019). Notably, involvement of type II muscle fibers and rapid movements during RST could be the underpinning mechanisms for these observed improvements (Boulossa et al., 2022).

Examination of group-specific responses indicated that shorter sprint intervals (3 sec) elicited the greatest

improvements in CMVJ, 10- and 20-m sprint performance, RSI, and peak power output. The 6-sec interval produced moderate but consistent gains across these variables, whereas the 9-s interval resulted in comparatively smaller adaptations, particularly in explosive and speed-related measures. For example, the 3-sec group’s improvements were especially pronounced in vertical jump and sprint metrics, suggesting that these adaptations were driven not solely by shorter absolute recovery (~9 sec), but by sprint-bout-duration-specific neuromuscular and energy-system demands. Shorter maximal efforts likely emphasized rapid force production, motor-unit recruitment, and ATP-PCr turnover, whereas longer all-out sprints (e.g., 9 s) imposed greater glycolytic stress and fatigue accumulation, potentially constraining repeated neuromuscular output despite longer recovery periods (Zhang et al., 2024). The findings resonate with the concept that abbreviated inter-bout recovery elevates metabolic demand, encourage efficient phosphagen system restoration, and forces muscle fibers to repeatedly reach high activation levels, all of which support performance gains in tasks requiring explosive

power (Harris et al., 1976).

Interestingly, the 9-sec group, despite showing overall significant progress across all variables, exhibited relatively superior improvement in T-CODS and mean power output when compared with the shorter-trial groups. This possibly suggests that extended rest enables more complete phosphocreatine resynthesis and energy restoration, allowing for better quality-and ultimately greater adaptation-during repeated high-intensity efforts involving agility or sustained power (Rogers et al., 2024). These observations highlight the crucial role of session structure in targeting specific athletic qualities.

The moderate-to-large training effects observed in sprint performance and explosive strength (i.e., RSI) echo the findings of previous RST studies (Purkhús et al., 2016; Lee et al., 2020). Enhanced oxygen delivery and utilization, as well as increased aerobic and anaerobic enzyme activity, are plausible contributors (Kunz et al., 2019). In line with these mechanisms, the 3-sec group, which performed under higher cumulative metabolic stress due to shorter trials, might have accumulated more time near maximal intensity, facilitating adaptations tied to greater aerobic and anaerobic capacity (Laursen and Buchheit, 2019; Rey et al., 2024). Adaptations in power output metrics further underscore the importance of exercise trial duration. The 3-sec and 6-sec groups showed marked increases in peak power outputs, yet the 9-sec group excelled specifically in mean power outcomes. This is coherent with the principle that shorter intervals boost ATP-PCr (Tao et al., 2024), while longer durations in RST could enhance glycolytic system and oxidative enzyme activity leading to more gains through sustain physical performance tasks (Rey et al., 2024).

An important consideration when interpreting the present findings relates to the number of acceleration phases performed across groups. Although total sprint work time was matched, the 3-s sprint group completed a substantially higher number of sprint starts compared with others. This difference may have influenced adaptations in explosive performance, as short-duration sprints disproportionately emphasize the initial acceleration phase, which is characterized by high horizontal force production and rapid neuromuscular activation (Laursen and Buchheit, 2019; Rey et al., 2024; Tao et al., 2024). In volleyball, performance actions such as approach runs, defensive movements, and positional adjustments are predominantly initiated from repeated short accelerations rather than prolonged sprinting (Sheppard et al., 2007). Therefore, the greater exposure to acceleration mechanics in the 3-s condition may partly explain the observed improvements in explosive-related outcomes (Tao et al., 2024). Conversely, longer sprint durations likely impose greater metabolic stress and involve a higher contribution of maximal velocity phases, which may be less specific to the acceleration-dominant demands of volleyball (Tao et al., 2024). Accordingly, the present results suggest that both sprint duration and the frequency of acceleration efforts contribute to training adaptations; however, the higher number of accelerations performed in shorter sprint bouts may represent a key mechanism underlying explosiveness-related improvements in specific performance.

There are several limitations in the current research that should be acknowledged and carefully considered when interpreting the results. The small sample size in each group may limit generalizability and statistical power, though preliminary power analysis indicated adequacy. Additionally, the findings pertain specifically to young male volleyball players, leaving open questions about their applicability to female athletes or other age groups. Furthermore, the training intervention was of relatively short duration. The present investigation did not include direct quantification of biochemical markers or fatigue-related indices following the RST protocols, variables that could have influenced the observed outcomes. Future research should incorporate such measures to validate or refute the current findings. In light of these methodological constraints, the outcomes reported herein should be considered preliminary, underscoring the necessity for subsequent studies to substantiate or challenge these observations.

Conclusion

This study demonstrates that young volleyball players exhibit distinct performance adaptations in response to different RST interval durations, with shorter, moderate, and longer sprint bouts eliciting differential effects on jumping ability, sprint performance, change-of-direction speed, and power-related outcomes. The 6-sec RST protocol consistently elicited moderate adaptations across most performance outcomes, positioning this condition between the 3- and 9-sec groups. Specifically, shorter sprint bouts (3 sec) were more favorable for enhancing explosive performance and sprint acceleration, whereas longer bouts (9 sec) tended to support greater improvements in change-of-direction speed and mean power output. Accordingly, the 6-sec condition appears to represent a balanced stimulus, producing meaningful but less pronounced adaptations across both neuromuscular and power-related domains. These findings indicate that athletes exhibit duration-dependent responses to RST, and coaches may strategically tailor sprint bout duration according to targeted performance qualities.

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Key points

- All RST protocols improved physical fitness.
- Shorter bouts favored explosive performance.
- Longer bouts favored agility and sustained output.
- Manipulating RST bout durations allows targeted performance development.

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