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Effects of Short-Rest Interval Time on Resisted Sprint Performance and Sprint Mechanical Variables in Elite Youth Soccer Players

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Abstract: This study explored the impact of short rest intervals on resisted sprint training in elite youth soccer players, specifically targeting enhanced initial-phase explosive acceleration without altering sprint mechanics. Fifteen U19 soccer players participated in a randomized crossover design trial, executing two sprint conditions: RST2M (6 sprints of 20 m resisted sprints with 2 min rest intervals) and RST40S (6 sprints of 20 m resisted sprints with 40 s rest intervals), both under a load equivalent to 30% of sprint velocity decrement using a resistance device. To gauge neuromuscular fatigue, countermovement jumps were performed before and after each session, and the fatigue index along with sprint decrement percentage were calculated. Interestingly, the results indicated no significant differences in sprint performance or mechanical variables between RST2M and RST40S, suggesting that the duration of rest intervals did not affect the outcomes. Horizontal resistance appeared to mitigate compensatory patterns typically induced by fatigue in short rest periods, maintaining effective joint movement and hip extensor recruitment necessary for producing horizontal ground forces. These findings propose a novel training strategy that could simultaneously enhance sprint mechanics during initial accelerations and repeated sprint abilities for elite youth soccer players—a methodology not previously employed

Keywords: resisted sprint; sprint mechanics; repeated sprint; rest interval time; soccer

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1. Introduction

Soccer is a sport that demands frequent high-intensity actions, particularly explosive acceleration sprints, which are crucial for success during matches. During competitive play, soccer players typically perform 91–119 high-intensity accelerations ($\geq$2.5–3 m/s^2) and 16–27 sprints ($\geq$24–25.2 km/h) with incomplete rest periods of between approximately 30 s or less and 60 s [1–5]. Short sprints ($\leq$10 m) and straight-line sprints are the most frequent movements preceding goal situations in soccer matches, with elite players exhibiting greater sprint distances and higher acceleration frequencies than non-elite players [6]. Recent research has shown that in both adult and youth players, explosive initial acceleration ($\leq$20 m) during matches and sprint performance decline as the season progresses [7–12]. Therefore, repeatedly performing and improving explosive acceleration sprints throughout matches and seasons is a key factor for better performance.

Soccer players often perform sprint training with short rest intervals ($\leq$60 s) to improve their ability to perform repeated sprints [13–18]. Adaptation to these short rest intervals between sprints can enhance recovery mechanisms and the activity of enzymes involved in both aerobic and anaerobic energy production [19]. Therefore, coaches may attempt to reduce rest intervals or increase training volume to achieve high intensities, but this approach could lead to exhaustion, and adversely affect sprint mechanics [14,17,20–24]. Moreover, while players and coaches often expect this training to enhance explosive acceleration from the start (0–20 m), research has revealed that it works best at 20–30 m [15,18,25,26]. In this study, the term sprint mechanics is employed due to its direct relevance to the measured variables, which are inherently linked to the mechanics of sprinting. Numerous previous studies have used the term sprint mechanics.

Explosive acceleration sprints require producing horizontal forces in the anterior-posterior (AP) direction onto the ground with effective mechanics to reduce braking forces and enhance propulsion [10,27–32]. However, continued training with altered sprint mechanics due to short rest intervals could affect athletes' movement patterns as they adapt to compensated sprint patterns [13,14,17,21–24,33]. This adaptation can cause changes in the maximum velocity sprint mechanics and performance [28,30,34,35]. To address these issues, several researchers have studied methods to maintain high sprint performance during repeated sprint training by manipulating the distance, rest periods, and volume distribution [22,36–39]. However, these attempts have been limited to improving the sprint mechanics and ground force output directly and, also, the opportunity for enhancement and adaptation of the energy metabolism system required by soccer players may be reduced.

Resisted sprint training is a primary method of improving short sprint performance in soccer players [26,40–44]. It can enhance the horizontal force output in the AP direction and mechanical efficiency by adjusting the trunk angle to effectively accelerate the body forward [40,44–48]. Recent studies have shown that loads of 30–50% sprint velocity decrement (Vdec; a load of percentage decrement to the maximum sprint velocity) are effective for initial acceleration mechanics (0–20 m) and have been used in practice and research [28,40,41,47,49–51]. However, traditional resisted sprint training has been biased toward improving mechanics and single sprint performance without considering the metabolic stresses required by soccer players. Coaches should consider not only sprint mechanics to improve the amount and direction of horizontal force applied to the ground but also physiological loading to enhance the capacity for repeated explosive acceleration. However, current training methods have either focused solely on increasing the physiological load or on separating training to improve sprint mechanics.

We reviewed a pioneering study that introduced elastic band resistance for sprint mechanical efficiency in repeated sprint training protocols for elite youth soccer players, aged 17 ± 0.3 years [25]. This study revealed that sprint performance improved during the late acceleration phase (20–30 m) but not during early acceleration. These results are similar to those of other forms of repeated sprint training. Therefore, they are unlikely to solve the current problems. In addition, it is known that post-peak height velocity (PHV) in youth athletes (age: 15.2 ± 1.6 years) that participated in the previous study requires neurological and morphological adaptation to improve sprinting [42,52,53]. Post-PHV athletes also need to develop initial acceleration, for which the level of lower limb strength to overcome inertia is critical; therefore, a higher resistance than the elastic band should be considered from the initiation of acceleration [54,55]. Furthermore, the study did not investigate how resistance with a short rest interval affects sprint performance and mechanical characteristics during training. This makes it challenging for practitioners to design and apply training methods based solely on the findings of this study. Therefore, new training approaches are necessary to improve short sprint performance in soccer players and help them repeatedly execute efficient accelerations, even when fatigued.

The present study aimed to examine the effects of a short rest interval on resisted sprint performance and sprint mechanical variables in elite youth soccer players to determine whether brief recovery periods could be used for resisted sprint training for soccer short sprint performance. Two types of training were compared: (a) RST2M, which involved six repetitions of 20 m resisted sprints with a 2 min rest interval (traditional), and (b) RST40S, which involved six repetitions of 20 m resisted sprints with a 40 s rest interval (repeated sprint protocol). Under both conditions, a load of 30% Vdec was applied. Furthermore, to evaluate and compare neuromuscular fatigue levels after each procedure, players performed a countermovement jump (CMJ) before and after each condition. We hypothesized that RST40S would exhibit lower performance and alterations in mechanical variables compared with RST2M in overall 0–20 m distance. Previous studies have focused on maintaining sprint quality through manipulation of rest periods, sprint distance, and volume. However, our study was designed to develop a novel training methodology that enhances the ability to perform repeated explosive accelerations with effective sprint mechanics while maintaining high exercise intensity.

2. Materials and Methods

2.1. Participants

In G*Power (version 3.1), an a priori analysis was conducted using a two-tailed test with an effect size of 0.95. The significance level was set at $\alpha = 0.05$ and the power at 0.80. This analysis estimated that the minimum sample size required per group in a two-sample *t*-test scenario would be 19 participants [22,37,39,56]. However, due to constraints in available resources and the high specificity of the elite athlete population targeted in our study, a smaller sample size was deemed necessary and acceptable. This decision was supported by the high effect size, which suggests that even with fewer participants, significant effects could still be detected reliably. Consequently, 15 young male soccer players representing U19 teams from a professional soccer academy participated in this study (mean ± standard deviation [SD]: age, 17.53 ± 0.51 years; height, 177.53 ± 4.35 cm; weight, 73.99 ± 4.94 kg). The inclusion criteria were as follows: (a) no previous injuries within 3 months, (b) previous experience with both resistance sprint and repeated sprint, and (c) participation in regular resistance sprint and repeated sprint in the off-season and preseason training. Goalkeepers were not included in the participants.

All the experiments were conducted during the preseason period. All players performed approximately 15 h of combined soccer-based training and competitive matches per week (5–6 soccer training sessions, 1–3 gym sessions, and 1 domestic game per week). All participants read and signed an informed consent form and were informed of the study objectives and procedures before participating in the study. All Players were younger than 19 years at the start of the experiment; therefore, players and parents were informed about the aims, benefits, and risks and signed a written informed consent form before participating in the study. This study was approved by the Institutional Ethics Committee of CHA University (1044308-202310-HR-128-03). The protocols were performed in accordance with the Declaration of Helsinki.

2.2. Study Design and Procedures

The study was performed in a randomized crossover design, and all participants performed three sessions across a 2-week period that included one load–velocity profile test for each individual load and two repeated sprint test sessions using the 1080 Sprint (1080 Motions, Stockholm, Sweden) for each individual load and variables (sprint time, peak force, power, velocity, step length, and stride frequency at 5 m split distance (0–20, 0–5, 5–10, 10–15, and 15–20 m). This is a resistance training device with intelligent drag technology and was developed for resisted and assisted sprint training that uses a servo motor (2000 RPM OMRON G5 Series Motor; OMRON Corporation, Kyoto, Japan). It can collect precise and frequent data on the velocity and pulling force exerted by the cable coiled around a spool. Recent studies suggest that the 1080 Sprint is valid and reliable for sprint performance and spatiotemporal variables [57–60], and has been used in resisted sprint training for field and research [28,61–64]. Data (time, force, and velocity) were recorded at 333 Hz.

The load–velocity profile was based on that in previous studies. To determine the load–velocity (L–v) relationship, all participants performed 1, 5, 8, 12, and 15 kg of resisted sprint at 35, 30, 25, 20, and 15 m, respectively [28,40]. The “normal mass resistance mode” was used, simulating the inertial properties of a normal mass (a cable-driven weight stack) in gravity “http://1080motion.com/ (accessed on 6 June 2024)”. Previous research suggests that loads of 30% Vdec to loads of 50% Vdec are effective for initial acceleration [28,40,47]. The range of the loads considered very heavy resistance (>30% velocity decrement) in the classification of resisted sprint loads [65]. We chose to use 30% Vdec loads in this study, given that the athletes may have relatively low levels of muscular strength and would need to perform sprints repeatedly after a short 40 s rest period [13,18,39]. The loads of 30% Vdec for the participants was an average value of 10.9 ± 0.79 kg. We employed rounding-up calculations to determine the load in the device.

One week later, two sessions of resistance sprints were performed. Each session was separated by 48–72 h, and the other conditions were kept constant except for the rest interval. The temperature within the facility was controlled by an air conditioning system, and no wind was applied to the indoor wooden basketball court to prevent air resistance. The temperature and humidity during the experiment were 18–20 °C and 30–45%, respectively.

All players were randomly assigned to either RST2M (Resisted Sprint Training with a 2 min rest interval) or RST40S (Resisted Sprint Training with a 40 s rest interval). To investigate the differences between RST2M and RST40S, they performed 6 repetitions of 20 m resisted sprints with 2 min and 40 s rest intervals, respectively, with Vdec (30%) load using 1080 Sprint (1080 Motion, Stockholm, Sweden). Prior to the test session, all participants performed a warm-up protocol, including 10 min of jogging, ~10 min of dynamic warm-up, ~10 min of sprint drill exercises, 2–4 submaximal to maximal sprints, and 2–3 resisted sprints under the 30% Vdec load as the test trials from a standing split-stance position (2-point stance).

The resistance load was regulated using the Quantum computer application (1080 Motion), which also recorded all sprinting data for subsequent analysis. The 1080 Sprint was placed approximately 3 m behind the starting line, with the motor cord secured to the belt around the pelvis of the athlete. And the front foot placed on the start line. The athletes started from the 2-point stance and were instructed to start with the cues 3 s before (“3. . .2. . .1. . .GO!”). Quantum software can identify the athlete’s position and initiate data collection at the start of their movement over a predetermined distance (20 m). It also features a stopwatch that works simultaneously at the end of each sprint to inform researchers about the amount of rest time given to participants.

To minimize fatigue and obtain more accurate sprint data, the researcher removed the harness from the waist of the athlete at the end of each trial and moved it back to its starting position. The athletes recovered by walking from the finish to the starting line. This is because the equipment provides a constant pulling resistance, otherwise the athlete would have a high eccentric load when returning to the starting point. The distance from the finish line to the start line was covered in approximately 20 s by walking. Upon the athletes’ arrival at the start line, one of the research staff provided assistance by wearing the belt. Subsequently, another assistant informed the participants 5 s before the following sprint. We chose active recovery based on previous studies to promote greater physiological stress than passive recovery and the specific characteristics of a soccer match [18].

To investigate and compare the neuromuscular fatigue level that occurs after each repeated sprint condition, countermovement jumps (CMJs) were conducted pre- and post-intervention with a 5 min rest [66–69]. Participants performed the three CMJs pre- and post- each intervention, and the average value of the three jumps was used for the analysis. ForceDecks Lite 400 (Vald Performance, Brisbane, Australia) was used to collect jump height, take-off velocity, and CMJ depth. The data were calculated automatically and in real time using the ForceDecks Lite 400 from VALD HUB. The participants were instructed to jump as high as possible on the force plate with their hands placed on their waists until completion. They were then asked to bend their knees to a self-selected position, jump as high as possible, and land gently to return to their starting position.

2.3. Statistical Analysis

All data from RSPTM and RST40S were confirmed to be distributed by the Shapiro–Wilk test; therefore, no further transformation was required. Data are presented as mean values (mean) and SD. A 2-Way (group × trial) analysis of variance (ANOVA) was performed for resisted sprint performance (time) and mechanical variables (peak speed, peak power, peak velocity, step length, and step frequency), all of which were calculated for each sprint distance (0–20, 0–5, 5–10, 10–15, and 15–20 m). An independent *t*-test was conducted to compare the differences of pre- and post-intervention in CMJ variables between RST2M and RST40S. To assess fatigue level, the fatigue index (FI) and Sdec (%) were used, and a paired *t*-test was conducted to analyze the differences between the groups. The FI (%) was derived using the best value as a reference and the last attempt, because the first attempt may not always be the best. The equation is as follows: (maximum−minimum value)/maximum value × 100. The Sdec (%) was calculated by dividing the total sprint time (TT) by the product of the peak sprint time (PT) and the number of sprints, subtracting one from the quotient, and multiplying the result by 100. The effect size (ES) was calculated using Hedges' g and partial eta squared (η^2) for the two-way ANOVA data to provide a comprehensive assessment of the magnitude of observed effects, considering both the study design and the analysis methods. Hedges' g was used for its suitability in adjusting for small sample biases in standardized mean differences, while partial eta squared (η^2) offers insight into the proportion of variance explained by our model in the context of ANOVA. Additionally, Cohen's d was employed for the CMJ variables, FI (%) and Sdec (%), facilitating comparisons between conditions within our study and enabling integration into broader meta-analyses. This varied approach allows for a more sophisticated interpretation of effect sizes that align with both intra-individual and between-subjects designs, enhancing the practical significance and cumulative scientific value of our findings. Statistical significance was set at $p < 0.05$. Statistical analyses were performed using the IBM SPSS Statistics 25 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Resisted Sprint Performance and Mechanical Variables

To investigate the impact of resisted sprint training with short rest periods on resisted sprint performance and mechanical variables, we compared the RST40S and RST2M. A 2-way ANOVA (group × trial) was performed to examine the effect of rest duration on the interaction effect between group and trial for the RST40S compared with the RST2M.

As shown in Table 1, there were no significant differences between RST2M and RST40S at 0–20 m ($p > 0.05$).

Table 1. Group × Trial differences in resisted sprint performance and mechanical variables at 0–20 m.

Sprint Variables	Group	M	SE	95% CI			ANOVA		
				LL	UL		Group	Trial	Group × Trial
Sprint time [s]	RST2M	4.05 ± 0.14	0.015	4.034	4.095	p	0.178	1.00	0.928
						F	1.835	0.013	0.271
	RST40S	4.03 ± 0.16	0.017	3.996	4.067	η^2	0.012	0.001	0.009
Peak speed [m/s]	RST2M	6.64 ± 0.28	0.030	6.561	6.680	p	0.494	0.997	0.356
						F	0.469	0.066	1.112
	RST40S	6.66 ± 0.25	0.027	6.594	6.703	η^2	0.003	0.002	0.034
Peak force [N]	RST2M	192.00 ± 21.51	2.281	186.741	196.102	p	0.590	0.194	0.678
						F	0.292	1.497	0.628
	RST40S	190.56 ± 21.72	2.303	184.839	194.378	η^2	0.002	0.046	0.020
Peak power [W]	RST2M	1059.95 ± 78.53	8.325	1036.495	1068.911	p	0.621	0.992	0.152
						F	0.246	0.099	1.641
	RST40S	1063.26 ± 68.39	7.249	1043.732	1072.527	η^2	0.002	0.003	0.050
AvgStep length [m]	RST2M	1.17 ± 0.04	0.005	1.155	1.176	p	0.230	0.750	0.912
						F	1.449	0.535	0.301
	RST40S	1.17 ± 0.05	0.006	1.164	1.186	η^2	0.010	0.017	0.010
AvgStep frequency [Hz]	RST2M	4.23 ± 0.19	0.020	4.200	4.283	p	0.906	0.837	0.996
						F	0.014	0.417	0.078
	RST40S	4.23 ± 0.18	0.020	4.203	4.286	η^2	0.000	0.013	0.003

M = mean; SE = standard error; CI = confidence interval; LL = 95% confidence interval lower limit; UL = 95% confidence interval upper limit; η^2 = partial eta squared.

The results in Table 2 reveal no significant differences between RST2M and RST40S at 0–5 m.

Table 2. Group × Trial differences in resisted sprint performance and mechanical variables at 0–5 m.

Sprint Variables	**Group**	**M**	**SE**	**95% CI**			**ANOVA**		
				LL	**UL**		**Group**	**Trial**	**Group × Trial**
Sprint time [s]	RST2M	1.51 ± 0.06	0.007	1.501	1.530	p	0.097	0.989	0.866
	RST40S	1.49 ± 0.09	0.010	1.474	1.514	F	2.790	0.114	0.344
						η^2	0.018	0.004	0.011
Peak speed [m/s]	RST2M	5.05 ± 0.20	0.021	4.992	5.073	p	0.218	0.849	0.815
	RST40S	5.08 ± 0.20	0.022	5.027	5.113	F	1.530	0.399	0.447
						η^2	0.010	0.013	0.014
Peak force [N]	RST2M	201.31 ± 10.66	1.131	198.470	203.129	p	0.709	0.687	0.500
	RST40S	201.74 ± 11.39	1.208	198.923	203.976	F	0.139	0.617	0.874
						η^2	0.001	0.019	0.027
Peak power [W]	RST2M	838.31 ± 66.35	7.034	818.232	844.401	p	0.757	0.840	0.775
	RST40S	841.62 ± 73.40	7.781	819.610	849.287	F	0.096	0.411	0.501
						η^2	0.001	0.013	0.016
AvgStep length [m]	RST2M	0.82 ± 0.06	0.006	0.811	0.837	p	0.107	0.620	0.803
	RST40S	0.84 ± 0.07	0.007	0.825	0.856	F	2.632	0.706	0.464
						η^2	0.017	0.022	0.015
AvgStep frequency [Hz]	RST2M	4.00 ± 0.21	0.023	3.968	4.062	p	0.571	0.756	0.868
	RST40S	4.02 ± 0.23	0.025	3.984	4.087	F	0.322	0.526	0.371
						η^2	0.002	0.017	0.012

M = mean; SE = standard error; CI = confidence interval; LL = 95% confidence interval lower limit; UL= 95% confidence interval upper limit; η^2 = partial eta squared.

There were no significant differences between RST2M and RST40S at 5–10 m (Table 3; $p > 0.05$).

Table 3. Group × Trial differences in resisted sprint performance and mechanical variables at 5–10 m.

Sprint Variables	**Group**	**M**	**SE**	**95% CI**			**ANOVA**		
				LL	**UL**		**Group**	**Trial**	**Group× Trial**
Sprint time [s]	RST2M	0.91 ± 0.02	0.003	0.911	0.923	p	0.151	0.976	0.796
	RST40S	0.91 ± 0.02	0.003	0.904	0.917	F	2.079	0.161	0.473
						η^2	0.16	0.008	0.016
Peak speed [m/s]	RST2M	6.03 ± 0.24	0.026	5.970	6.075	p	0.445	0.995	0.813
	RST40S	6.06 ± 0.23	0.025	6.000	6.103	F	0.586	0.080	0.449
						η^2	0.004	0.003	0.014
Peak force [N]	RST2M	163.61 ± 6.94	0.736	161.604	164.527	p	0.433	0.862	0.432
	RST40S	162.81 ± 7.57	0.803	160.609	163.796	F	0.618	0.380	0.979
						η^2	0.004	0.012	0.030
Peak power [W]	RST2M	955.18 ± 69.46	7.363	935.797	965.624	p	0.942	0.871	0.438
	RST40S	954.80 ± 72.33	7.667	934.495	965.326	F	0.005	0.366	0.970
						η^2	0.000	0.012	0.030
AvgStep length [m]	RST2M	1.21 ± 0.05	0.005	1.203	1.225	p	0.238	0.937	0.997
	RST40S	1.22 ± 0.05	0.006	1.213	1.235	F	1.402	0.254	0.068
						η^2	0.009	0.007	0.002
AvgStep frequency [Hz]	RST2M	4.42 ± 0.20	0.021	4.393	4.480	p	0.852	0.973	0.997
	RST40S	4.42 ± 0.19	0.021	4.387	4.473	F	0.035	0.171	0.066
						η^2	0.000	0.005	0.000

M = mean; SE = standard error; CI = confidence interval; LL = 95% confidence interval lower limit; UL = 95% confidence interval upper limit; η^2 = partial eta squared.

No significant differences between RST2M and RST40S at 10–15 m were observed (Table 4; $p > 0.05$).

Table 4. Group × Trial differences in resisted sprint performance and mechanical variables at 10–15 m.

Sprint Variables	Group	M	SE	95% CI		ANOVA			
				LL	UL		Group	Trial	Group × Trial
Sprint time [s]	RST2M	0.82 ± 0.03	0.003	0.823	0.836	p	0.584	0.998	0.878
	RST40S	0.82 ± 0.03	0.003	0.821	0.834	F	0.301	0.051	0.355
						η^2	0.000	0.000	0.013
Peak speed [m/s]	RST2M	6.49 ± 0.26	0.028	6.426	6.541	p	0.697	0.990	0.559
	RST40S	6.50 ± 0.25	0.027	6.443	6.555	F	0.152	0.109	0.789
						η^2	0.001	0.003	0.025
Peak force [N]	RST2M	160.23 ± 6.73	0.714	158.281	161.105	p	0.880	0.904	0.486
	RST40S	160.00 ± 6.39	0.678	158.198	160.889	F	0.023	0.314	0.850
						η^2	0.000	0.010	0.028
Peak power [W]	RST2M	1029.43 ± 78.26	8.296	1007.917	1041.745	p	0.896	0.952	0.503
	RST40S	1031.25 ± 73.98	7.843	1010.556	1042.209	F	0.017	0.223	0.870
						η^2	0.000	0.007	0.027
AvgStep length [m]	RST2M	1.37 ± 0.06	0.007	1.355	1.382	p	0.693	0.856	1.000
	RST40S	1.37 ± 0.06	0.007	1.358	1.386	F	0.156	0.389	0.009
						η^2	0.002	0.012	0.000
AvgStep frequency [Hz]	RST2M	4.41 ± 0.21	0.022	4.369	4.463	p	0.944	0.852	0.944
	RST40S	4.40 ± 0.21	0.022	4.367	4.460	F	0.005	0.012	0.241
						η^2	0.000	0.395	0.008

M = mean; SE = standard error; CI = confidence interval; LL = 95% confidence interval lower limit; UL = 95% confidence interval upper limit; η^2 = partial eta squared.

Table 5 demonstrates no significant differences between RST2M and RST40S at 15–20 m.

Table 5. Group × Trial differences in resisted sprint performance and mechanical variables at 15–20 m.

Sprint Variables	Group	M	SE	95% CI		ANOVA			
				LL	UL		Group	Trial	Group × Trial
Sprint time [s]	RST2M	0.80 ± 0.03	0.004	0.793	0.809	p	0.664	0.992	0.474
	RST40S	0.79 ± 0.03	0.004	0.791	0.806	F	0.189	0.100	0.913
						η^2	0.000	0.005	0.030
Peak speed [m/s]	RST2M	6.63 ± 0.28	0.030	6.558	6.677	p	0.474	0.997	0.366
	RST40S	6.66 ± 0.25	0.027	6.593	6.702	F	0.515	0.067	1.094
						η^2	0.003	0.002	0.034
Peak force [N]	RST2M	159.50 ± 6.73	0.714	157.518	160.310	p	0.631	0.748	0.251
	RST40S	159.83 ± 6.15	0.652	158.084	160.668	F	0.232	0.536	1.337
						η^2	0.001	0.017	0.041
Peak power [W]	RST2M	1055.14 ± 79.16	8.391	1031.358	1063.856	p	0.492	0.954	0.174
	RST40S	1060.45 ± 68.78	7.291	1040.713	1069.591	F	0.473	0.220	1.562
						η^2	0.003	0.007	0.048
AvgStep length [m]	RST2M	1.49 ± 0.08	0.009	1.473	1.510	p	0.185	0.125	0.879
	RST40S	1.50 ± 0.08	0.009	1.491	1.527	F	1.773	1.757	0.355
						η^2	0.012	0.053	0.012
AvgStep frequency [Hz]	RST2M	4.22 ± 0.26	0.028	4.164	4.282	p	0.345	0.265	0.915
	RST40S	4.18 ± 0.25	0.027	4.127	4.241	F	0.896	1.304	0.296
						η^2	0.006	0.040	0.009

M = mean; SE = standard error; CI = confidence interval; LL = 95% confidence interval lower limit; UL = 95% confidence interval upper limit; η^2 = partial eta squared.

3.2. FI (%) and Sdec (%)

Table 6 demonstrates no significant differences between RST2M and RST40S for FI (%) (4.61 ± 2.20 vs. 3.92 ± 2.54, $p > 0.05$) and Sdec (%) (2.17 ± 1.02 vs. 1.17 ± 1.05%, $p > 0.05$).

Table 6. Group differences in FI (%) and Sdec (%).

Fatigue Variables	**Group**	**M**	**SE**	**95% CI**		**Paired *T*-Test**		
				LL	**UL**	**t**	***p***	**ES**
FI (%)	RST2M	4.61 ± 2.20	0.568	2.39	1.00	−0.874	0.397	0.22
	RST40S	3.92 ± 2.54	0.656					
Sdec (%)	RST2M	2.17 ± 1.02	0.26	−0.47	1.28	0.986	0.341	0.25
	RST40S	1.17 ± 1.05	0.27					

M = mean; SE = standard error; CI = confidence interval; LL = 95% confidence interval lower limit; UL = 95% confidence interval upper limit; FI (%) = fatigue index; Sdec (%) = percentage of sprint time decline.

3.3. CMJ Characteristics

As demonstrated in Table 7, no significant differences were observed between RST2M and RST40S in the post–pre differences of height (−1.95 ± 2.09 vs. −0.31 ± 2.60 s, $p > 0.05$), take-off velocity (−0.06 ± 0.7 vs. −0.01 ± 0.09, $p > 0.05$), and CMJ depth (−0.98 ± 5.41 vs. −0.72 ± 2.03, $p > 0.05$).

Table 7. Group differences in CMJ characteristics.

CMJ Variables	**Group**	**Pre**	**Post**	**Post–Pre**	**SE**	**Post–Pre 95% CI**		**Independent *T*-Test**	
						LL	**UL**	***p***	**ES**
Height (cm)	RST2M	40.63 ± 4.21	38.68 ± 3.44	−1.95 ± 2.09	0.541	−3.407	0.127	0.068	0.71
	RST40S	39.86 ± 4.23	39.54 ± 3.89	−0.31 ± 2.60	0.671				
Take-off Velocity (m/s)	RST2M	2.82 ± 0.14	2.75 ± 0.12	−0.06 ± 0.7	0.019	−0.118	0.005	0.073	0.70
	RST40S	2.79 ± 0.14	2.78 ± 0.13	−0.01 ± 0.09	0.023				
CMJ Depth (cm)	RST2M	−29.44 ± 6.62	−30.43 ± 6.18	−0.98 ± 5.41	1.397	−3.325	2.792	0.860	0.06
	RST40S	−30.26 ± 5.77	−30.98 ± 5.86	−0.72 ± 2.03	0.526				

SE = standard error; CI = confidence interval; LL = 95% confidence interval lower limit; UL = 95% confidence interval upper limit; CMJ, countermovement jump.

4. Discussion

4.1. Resisted Sprint Performance and Mechanical Variables

The results showed that sprint times and peak speed were not significantly different between RST2M and RST40S when group and trial were included as two independent variables in a two-way ANOVA. This study's analysis went beyond simply examining differences between groups. Despite conducting sophisticated analyses on a trial-by-trial basis, no significant differences were observed. Furthermore, there are no studies that have analyzed horizontal pull-resisted sprints within a repeated sprint protocol, and it is also difficult to find prior research examining changes in resisted sprint performance based on rest intervals. Consequently, this limits the direct comparison of the results of this study with previous research.

A recent literature review [18] reveals that the typical repeated sprint training set figuration consists of 6 repetitions of 30 m straight-line sprints with 20 s rests between repetitions. Shorter rest intervals (≤20 s) and longer sprint distances (≥30 m) substantially increase physiological demands and lead to greater fatigue between sets. In contrast, longer rest intervals (≥30 s) and shorter sprint distances (≤20 m) enhance immediate sprint performance and reduce physiological strain. Many recent studies on resisted sprints utilize protocols involving 6–8 repetitions of 20 m resisted sprints with rest periods of 2 min or more, as sufficient recovery is essential for the muscular power output required during resisted sprints. Prior research indicates that resisted sprint training with complete rest typically results in higher blood lactate levels, indicative of anaerobic energy exercise intensity, compared to non-resisted sprint training [47,70,71].

Peak force and peak power showed no significant differences between RST2M and RST40S across the entire 20 m distance. The results of this study contrast with previous research on repeated sprint training performed with unresisted sprints. Prior studies have shown that during repeated sprints, fatigue leads to greater decreases in force and power output in the first and later phases of sprinting [24,33,72–74]. Sustaining sprints with reduced force and power applied by the neuromuscular system makes it difficult to achieve positive adaptations on maximal and repeated sprint ability for soccer players [75]. The principle of resisted sprint training is to apply greater force to the ground compared to unresisted sprints [55,64,65]. The neuromuscular system adapts by generating more force to overcome the resistance, thereby improving acceleration sprint performance [55,61,65,76].

AvgStep length and frequency did not differ significantly between RST2M and RST40S across the entire 20 m distance. The findings of this study differ from previous research that observed changes in step length and step frequency during repeated sprints [21,77,78]. Earlier studies typically involved sprint distances exceeding 30 m with rest intervals of less than 30 s, with participants performing between 6 and 12 sprints. Alterations in step length and frequency during repeated sprints are thought to result from decreased vertical leg stiffness [14,77]. Vertical leg stiffness, which describes how rigidly the body behaves like a spring, absorbing and releasing energy efficiently, diminishes with repeated sprints and is linked to alterations in neuromuscular activation and muscle oxygenation rates. Moreover, fatigue from repeated sprints is generally known to cause changes in knee and hip momentum at the beginning of acceleration sprints, as well as in the coordination of posterior chain muscles such as the glutes and hamstrings [28,44,45].

This study presented results that contrasted with those of typical repeated sprint training protocols. To understand these phenomena, further research is needed to elucidate the underlying mechanisms. Additionally, it is necessary to verify whether protocols like RST40S exert physiological stress equivalent to the estimated benchmarks for repeated sprint training intensity in team sport athletes, which include HRavg at 90% HRmax, VO2avg at approximately 70–80% VO2max, and blood lactate concentration (B[La]) of 10.8 mmol/L [18]. Intervention studies should also be conducted to determine whether these findings can serve as a new method for improving repeated acceleration sprint performance in elite youth soccer players. These attempts may contribute to a new perspective in resisted sprint research, suggesting that rest periods would be tailored to sport-specific demands, contrasting with the prevailing trends in load setting and the kinematic effects of resisted sprinting.

4.2. FI (%) and Sdec (%)

FI (%) and Sdec (%) also showed no significant differences between RST2M and RST40S. Both groups exhibited lower FI (%), ranging from 10% to 15%, and Sdec (%), ranging from 5% to 7% values compared to those reported in previous studies conducted with youth soccer players [15,79,80]. FI (%) reflects overall performance impact and recovery capacity between sprints. Sdec (%) indicates the rate of performance decline during repeated sprints and the ability to sustain high performance under fatigue, with lower values demonstrating better endurance. Direct comparison with typical repeated sprint protocols is limited due to the specific characteristics of this study. However, the lack of significant differences between the two groups suggests that elite youth soccer players can recover and maintain performance without long rest periods, even when performing 20 m sprints with a 30% Vdec load. This finding implies that shorter recovery times may be sufficient for maintaining performance in this training context. Nevertheless, since the effects of protocols like RST40S compared to traditional resistance protocols like RST2M after 24 and 48 h have not been analyzed, it cannot be assumed that they impose the same physiological stress on the body. Future research should explore these long-term effects to determine the most effective training protocols.

4.3. CMJ Characteristics

The pre- and post-comparison differences between the groups were not significant in CMJ characteristics. The countermovement jump (CMJ) is frequently used as an indicator to assess fatigue levels during sprint performance, which in turn allows for the adjustment of training volume and intensity [66–69]. Both groups appeared to exhibit performance declines following resisted sprints, consistent with previous research. Under fatigue, jump height and take-off velocity tend to decrease, and a deeper countermovement depth may occur to increase eccentric load for generating greater force. The lack of significant differences between the groups suggests that the neuromuscular fatigue levels immediately after performing the RST40S protocol were similar to those of RST2M. However, since the exact exercise intensity of RST40S is currently difficult to determine and CMJ was measured only once, five minutes after each condition, it is challenging to assert that it induces the same level of neuromuscular fatigue as RST2M [69].

4.4. Limitations and Future Research Directions

This study has some limitations. Although we conducted an a priori power analysis to determine the sample size based on previous studies' sample sizes, the small sample of 15 young elite male soccer players may limit the generalizability of the findings. For future research, expanding the sample size and youth female athletes would enhance the generalizability of the results. Additionally, this study had a randomized crossover design, which is robust, but it only involved three sessions across a 2-week period. A longer intervention period or additional sessions with more sprints or sets could provide a more comprehensive understanding of the effects of short rest intervals on resisted sprint performance. Lastly, we did not measure the changes of muscle activation patterns or aerobic and anaerobic metabolism. Future research that includes these measurements could provide deeper insight into why short rest intervals did not affect performance as hypothesized.

5. Conclusions

This study extends the understanding of sprint training in elite youth soccer players by exploring the impact of short rest intervals on resisted sprint performance and mechanics. Unlike earlier studies, no statistically significant differences were found in sprint time, mechanical variables, FI (%), Sdec (%), or CMJ variables between the RST2M and RST40S groups. The findings indicate that soccer players may be able to maintain their resisted sprint performance with a 30% load during short rest periods. This observation suggests the potential for short rest periods to be integrated into sprint training, although further research is necessary to confirm these trends.

Further research is required to develop this training method into an evidence-based practice, identify optimal resistance levels, and investigate metabolic characteristics. Verifying if RST40S exerts equivalent physiological stress to established benchmarks is crucial for refining training protocols to meet sport-specific demands. Long-term studies should determine if these findings improve sprint performance, suggesting tailored rest periods for athletes. Finally, the study's limitations, such as the small sample size and short intervention period, highlight the need for more comprehensive research to confirm and expand these findings.

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