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Resisted sprint training with partner towing improves explosive force and sprint performance in young soccer players – a pilot study

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ABSTRACT: The purpose of this study was to examine the effects of non-resisted (NRS) and partner-towing resisted (RS) sprint training on legs explosive force, sprint performance and sprint kinematic parameters. Sixteen young elite soccer players (age 16.6 ± 0.2 years, height 175.6 ± 5.7 cm, and body mass 67.6 ± 8.2 kg) were randomly allocated to two training groups: resisted sprint RS (n = 7) and non-resisted sprint NRS (n = 9). The RS group followed a six-week sprint training programme consisting of two "sprint training sessions" per week in addition to their usual soccer training. The NRS group followed a similar sprint training programme, replicating the distances of sprints but without any added resistance. All players were assessed before and after training: vertical and horizontal jumping (countermovement jump (CMJ), squat jump (SJ), and 5-jump test (5JT)), 30 m sprint performance (5, 10, and 20 m split times), and running kinematics (stride length and frequency). In the RS group significant ($p < 0.05$) changes were: decreased sprint time for 0–5 m, 0–10 m and 0–30 m (-6.31, -5.73 and -2.00%; effect size (ES) = 0.70, 1.00 and 0.41, respectively); higher peak jumping height (4.23% and 3.59%; ES = 0.35 and 0.37, for SJ and CMJ respectively); and 5JT (3.10%; ES = 0.44); and increased stride frequency (3.96%; ES = 0.76). In the NRS group, significant ($p < 0.05$) changes were: decreased sprint time at 0–30 m (-1.34%, ES = 0.33) and increased stride length (1.21%; ES = 0.17). RS training (partner towing) for six weeks in young soccer players showed more effective performances in sprint, stride frequency and lower-limb explosive force, while NRS training improved sprint performance at 0–30 m and stride length. Consequently, coaches and physical trainers should consider including RS training as part of their sprint training to ensure optimal sprint performance.

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INTRODUCTION

Sprint ability represents an important determinant of success in modern team sports such as soccer [1–3]. During a competitive soccer game, players can perform > 81 sprints per match [4]. Several training modalities have been proposed to enhance the sprinting ability of soccer players. Combined strength, power and sport-specific drills have produced improvement in soccer players' sprint ability [5–7]. Plyometrics training has also been reported to have a positive effect on sprint performance of soccer players [8–10]. Additionally, the combination of high-intensity interval training bouts in conjunction with heavy-load strength training has been shown to enhance sprinting capability in soccer players [11]. Moreover, along with traditional sprint training, resisted-sprint (RS) training represents another method of developing sprinting capability [12]. RS training has been defined as an addition of resistance to the player's body in many forms (e.g. parachutes, sled towing or harnesses) [13]. Regarding the scientific literature, most resisted-sprint training studies have focused on the effect of sled-towing methodologies on sprint and speed performance [14–17]. To date, studies regarding the effectiveness of RS training on sprinting ability have shown that sled-towing training improved sprint performance, by resulting in positive changes to acceleration and/or maximal velocity and lower-limb force when compared with traditional NRS training [18–20]. Petrakos et al. [18] reported that in sprint trained individuals, RS training with 'light' (< 10% BM) loads provide 'small' decrements in acceleration (-1.5%, ES = 0.50) to 'moderate' improvements in maximal sprint velocity (2.4%, ES = 0.80). In strength-trained or team sport individuals, 'Moderate' (10–19.9%BM) to 'very heavy' (30% BM) sled loads provide 'trivial' to 'extremely large' improvements in acceleration performance (0.5–9.1%, ES = 0.14–4.00). On the other hand, Rumpf et al. [20] showed that this type of training increases velocity via increased step frequency, increased horizontal force and power production.

In addition to sled towing, there are other modalities of resisted sprint training that can be used to overload the players whilst sprinting, e.g. sprinting with partner resistance. The use of such equipment overcomes issues of damaging indoor and/or outdoor surfaces and also provides many options in terms of training, e.g. varying resistance while sprinting and/or instantaneous release of partner for speed and lower-limb force development. Unfortunately, there is no reference in the literature describing the latter points that we have mentioned according to practical observations from the field. We hypothesized that the use of the partner-towing training method will result in positive training adaptations among young elite soccer players, i.e. improved sprint acceleration phases and sprint kinematics. However, as such a contention needed to be investigated, the aim of this study was to quantify the effects of partner towing on leg explosive force, sprint performance and sprint kinematic parameters in young elite soccer players.

MATERIALS AND METHODS

Experimental Approach to the Problem

A longitudinal repeated cross-sectional study design was used, involving repeated observations over a six-week period. All testing were carried out the same day on an indoor hall rubberized track, at the same time of day (9:00 to 11:00 am). Environmental temperature range was 18–20°C and humidity 65–75%. During all test sessions, players were asked to wear indoor trainers for testing and soccer boots during grass training sessions, in a consistent way through the experiment. Two hours before testing, the athletes were given the same breakfast, consisting of one cake, a glass of orange juice and ad-libitum water in a consistent way during the period of the protocol. Before and after the 6-week training programme, running speed (30 m) with split times at 5, 10 and 20 m, power test (vertical and horizontal jumps) and kinematics (stride length and frequency) were assessed. Two familiarization sessions were performed during the week preceding the first testing session. Players were randomly assigned to two training groups (resisted sprint training group (RS, n = 7) and non-resisted sprint training group (NRS, n = 9). The RS group trained using the partner-towing sprinting, while the NRS group completed the same sprint training programme as the RS group but without any resistance. A 15 min standardized warm-up was performed before each testing and training session. Experimental sessions were administered during the competition phase (season starting in September and finishing in May). During the intervention period, the soccer training schedule consisted of 4/5 training sessions and one official game per week.

Subjects

U-17 male elite soccer players participated in the study and were randomly assigned to two training groups: resisted sprint training group (RS, n = 7); and non-resisted sprint training group (NRS, n = 9). A minimum sample size of 16 was determined from an "a priori" statistical power analysis using G*Power (Version 3.1, University of Dusseldorf, Germany). The power analysis was computed with an assumed power at 0.80 at an alpha level of 0.05, an effect size of 0.4. Players' anthropometric characteristics are presented in Table 1. They had at least four years of soccer practice in the first division of a national North African soccer league. Moreover, the players performed 5 football training sessions a week during the last 6 months. None of the participants had previous experience with specific sprint training and were healthy and had not had any injuries during the month preceding the experience. Skinfold thickness was measured to the nearest 0.2 mm at four predetermined sites (biceps, triceps, subscapular, and suprailiac) using Harpenden skinfold callipers (Lange, Cambridge, MA, USA). Percentage of body fat was estimated using the equations described by Durnin and Womersley. [21] The study was conducted according to the Declaration of Helsinki and the protocol was approved by the institutional ethics

TABLE 1. Age and anthropometric data of the participants.

	RS		NRS	
	Pre-training	**Post-training**	**Pre-training**	**Post-training**
Age (y)	16.6 ± 0.2	16.8 ± 0.2	16.6 ± 0.3	16.8 ± 0.3
Height (cm)	174.0 ± 6.4	174.6 ± 5.9	175.8 ± 5.3	176.4 ± 5.4
Body mass (kg)	67.3 ± 7.9	67.1 ± 6.0	67.9 ± 8.8	67.8 ± 8.4
Body fat (%)	13.6 ± 2.9	13.3 ± 2.6	13.4 ± 3.8	13.3 ± 3.1

* RS = resisted sprint; NRS = non-resisted sprint. †Data are presented as mean and SD.

committee. All participants and their parents/guardians were fully informed about the protocol, the risks and benefits of the study and signed written consent forms.

Procedures

Testing methods

Jump testing

Participants performed countermovement (CMJ) and squat jumps [22] starting from their preferred countermovement position to achieve the best performance [23]. Vertical-jump performance was assessed using a portable force platform (Quattro-Jump, Kistler 9281C, Winterthur, Switzerland) [24]. The best jump after 3 repetitions of each jumping protocol was selected for analysis. Absolute and relative peak jumping force (F_{peak}), peak jumping velocity (V_{peak}), peak jumping power (W_{peak}), and the peak height of the jumps (H_{peak})] were recorded [25]. A quintuple horizontal jump test (5JT) was also performed by the players as an assessment of horizontal leg power [24].

Sprint testing

Sprint performance over 30 m was assessed using timing photocells (Brower Timing Systems, Salt Lake City, UT; accuracy of 0.01 s) and 5, 10, and 20 m split-times were recorded [26]. All timing gates were placed 1 m above the ground and spaced 1.5 m apart (Figure 1). Players started in a standing position with their preferred foot forward exactly 0.5 m behind the first timing gate. The 30 m sprint test was repeated three times (with two minutes of rest) and the best sprint time was used for statistical analysis [26].

Kinematic analysis

Kinematic parameters were collected via a standard two-dimensional (2D) method (AG-DVX100B 3-CCD Mini DV, 60 Hz and shutter speed, 1/4000th of a second). Body markers were digitized using the Hanavan model modified by De Leva [27]. The video-based data analysis system SkillSpector 1.3.2 (Odense SØ–Denmark) with quantic-spline data filtering was used. Three mutually synchronized digital cameras (Time-Code Synchronization, TC-Link) were used to capture sagittal-plane video data over the 30 m distance. The cameras were placed to the left of the track line (10 m from the athlete and at a height of 1.10 m) [15] and were calibrated in 2D using a 1 m calibration cube with 4 retro-reflective body markers filmed in the optical plane for 10 s. A fourth camera was placed midway (at 15 m of sprinting distance) to allow filming of the whole sprint in order to count the number of strides. Stride analysis included stride frequency and stride length (point of foot strike of one foot to the point of foot strike of the contralateral foot). The participants were recorded for the entire run. If the feet did not land exactly on the line, then half-strides were counted [28]. The stride length and stride frequency were determined as follows: stride length = distance/stride number and was expressed in metres; stride frequency = stride number/time and was expressed as strides per second (or Hz) [29, 30].

Training programmes

It was impossible to quantify the resistance imposed by the partner, but there was an attempt to standardize and calibrate the intensity to be the same during all the repetitions, by performing half of the sprinted distance over 4 seconds (for the first part), then the player was released by his partner to finish the second half of the distance free sprinting: Weeks 1 and 2, players performed 10 m sprints with the instruction to perform the first 5 m in 4 seconds before being released to finish the distance free sprinting; Weeks 3 and 4, players performed 20 m sprints with the instruction to perform the first 10 m in 4 seconds before being released to finish the distance free

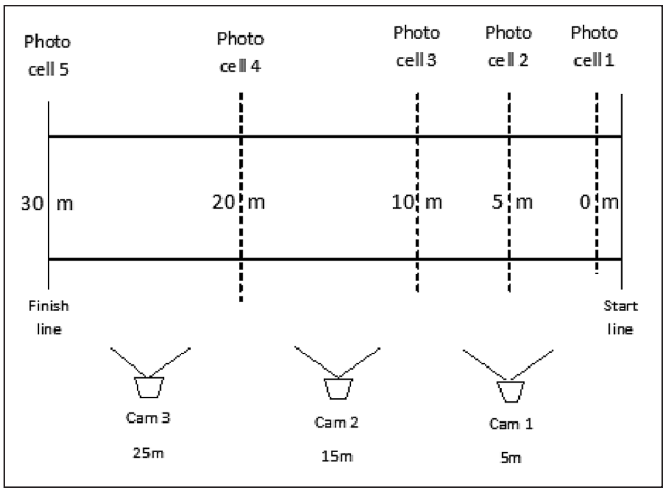

FIG. 1. Equipment setup used during data collection

FIG. 2. Resistance-sprint harness

TABLE 2. Summary of the sprint-training program for RS (n = 7) and NRS (n = 9) groups

Week	Sessions	[Distance (m) × repetition] × sets	Total distance/session (m)	Intensity (%)
1	1–2	[10 × 3] × 3	90	100%
2	3–4	[10 × 3] × 4	120	100%
3	5–6	[20 × 3] × 3	180	100%
4	7–8	[20 × 3] × 4	240	100%
5	9–10	[30 × 3] × 3	270	100%
6	11–12	[30 × 3] × 4	360	100%

Rest intervals between repetitions and sets were 1- and 3- minutes, respectively

sprinting. Weeks 5 and 6, players performed 30 m sprints with the instruction to perform the first 15 m in 4 seconds before being released to finish the distance free sprinting. Both training groups completed their respective training programme twice a week for 6 weeks. Both groups performed identical total sprinted distance during the training programme. However, the RS group performed sprint training with an additional resistance (partner towing; having a similar height and body mass) (Figure 2). Four familiarization sessions were performed during the two weeks preceding the training programme**.** Detailed information of the training programme is presented in Table-2.

Statistical analysis

Means and standard deviations [31] were used as measures of centrality and spread of data, respectively. Normality was verified using the Shapiro-Wilk test. On the basis of a power analysis (expected effect size = 40, desired power = 0.80, and alpha error = 0.05), we determined that a sample size = 16 would be sufficient to detect differences between groups. Within-group comparisons (Student paired t-test) were carried out to detect significant differences between the pre-test and post-test in any variable in both groups. The data were then analysed using multivariate analysis of variance (2 × 2) with repeated measures on the second factor. The factors included two separate groups of training (RS and NRS) and repeated measures of time (pre- and post-training). Because of slight initial differences between the 2 groups, analyses of covariance with the pre-test values as the covariate were used where necessary to determine significant differences between the post-test adjusted means. If significant main effects were found, a Bonferroni post-hoc analysis was performed. The effect size was calculated for all ANCOVAs using partial eta-squared. The values of 0.01, 0.06 and 0.15 were considered as small, medium, and large cut-off points, respectively [32]. Effect size (ES) was also calculated for all paired comparisons and evaluated with the method described by Cohen (small: < 0.50, moderate: = 0.50–0.80 and large: > 0.80). Reliability of the measures (dependent variables) was assessed twice over a number of days with a Cronbach's model intraclass correlation coefficient (ICC), standard error of measurements (SEM) and coefficient of variation (CV) according to the Hopkins method [33]. Sensitivity to discriminate the training effect was established from the receiving operator characteristic [34] curve analysis [35]. According to Deyo and Centor [36], an area under the ROC curve (AUC) > 0.70 is commonly considered to indicate good discriminant sensitivity of the test. Statistical analyses were performed using the SPSS software statistical package (SPSS Inc., Chicago, IL, version 16.0), and statistical significance was set at $p < 0.05$.

RESULTS

The ICC, SEM and CV values for all measures demonstrated 'high reliability': SJ height (ICC = 0.93, SEM = 0.62, CV = 3.2%, CMJ height (ICC = 0.96, SEM = 0.71, CV = 3.7%), 5JT (ICC = 0.85, SEM = 0.05, CV = 2.9%), sprint tests (ICC = 0.94 to 0.96, SEM = 0.02 to 0.03, CV = 1.4 to 4.6%) and kinematic parameters (ICC > 0.90 and CV < 5%). Furthermore a paired t-test showed no significant differences between the scores recorded during the test and retest for all the variables measured.

No significant pre-to-post training variations in anthropometric variables were found in either the RS or NRS group (Table 1). Means and standard deviations of dependent variables are reported in Tables 3–5.

Explosive force of lower limbs

A significant group × time interaction was noted for only the SJ tests: absolute F_{peak} ($F = 4.66$; $p < 0.05$; η^2 = large), relative F_{peak} ($F = 5.59$; $p < 0.03$; η^2 = large), H_{peak} ($F = 8.03$; $p < 0.01$; η^2 = large) and 5-jump test ($F = 20.28$; $p < 0.001$; η^2 = large). Significant group effects were observed for the SJ tests: absolute F_{peak} ($F = 5.39$, $p < 0.04$; η^2 = large), relative F_{peak} ($F = 7.59$, $p < 0.02$; η^2 = large), H_{peak} ($F = 6.75$, $p < 0.02$; η^2 = large) and 5-jump test ($F = 8.40$; $p < 0.01$; η^2 = large). After the training period, the RS group improved significantly in all explosive force tests ($p < 0.05$). Post-hoc analysis showed a significantly better post-training performance among the RS group performing better in comparison to the NRS group: absolute F_{peak} (4.71% vs -3.13%; $p < 0.04$; ES = large), relative F_{peak} (4.71% vs -3.33%; $p < 0.02$; ES = large), H_{peak} (4.23% vs -2.67%; $p < 0.02$; ES = large) and 5-jump (3.10% vs 0.00%; $p < 0.01$; ES = large), respectively (Table 3).

Sprint time at 5, 10, 20 and 30 m

The analysis of variance revealed a significant group × time effects for the 0–5 m sprint time only (F = 5.12; $p < 0.05$; η^2 = large). A significant group effect was observed for the 0–5 m sprint time, (F = 6.04, $p < 0.03$; η^2 = large). Greater improvement in 0–5 m sprint times ($p < 0.01$; ES = large) was found in the RS group compared

TABLE 3. Effect of 6-weeks of training on explosive force of lower-limbs (mean ± SD).

Parameter	RS				NRS				ANCOVA p-value (η^2)
	Pre-training	Post-training	Delta %	Cohen's *d*	Pre-training	Post-training	Delta %	Cohen's *d*	
SJ									
F_{peak} (kgf)	165.51 ± 25.27	172.26 ± 24.84*§	4.07	0.27	167.63 27.72	162.39 ± 21.82	-3.13	0.19	**0.04 (0.89)**
F_{peak} (kgf/kg)	2.55 ± 0.20	2.67 ± 0.25*§	4.71	0.60	2.40 ± 0.22	2.32 ± 0.19	-3.33	0.36	**0.02 (0.37)**
H_{peak} (cm)	40.86 ± 4.95	42.59 ± 5.06*§	4.23	0.35	43.46 ± 5.84	42.30 ± 4.34	-2.67	0.20	**0.02 (0.34)**
CMJ									
H_{peak} (cm)	42.63 ± 4.11	44.16 ± 3.80*	3.59	0.37	44.62 ± 5.77	44.18 ± 5.86	-0.99	0.08	0.17 (0.14)
W_{peak} (W/kg)	46.17 ± 5.45	46.65 ± 5.60	1.04	0.09	46.67 ± 6.08	45.89 ± 3.74	-1.67	0.13	0.27 (0.09)
5-jump									
Distance (m)	10.96 ± 0.78	11.30 ± 0.77*§	3.10	0.44	11.37 ± 0.53	11.37 ± 0.57	0.00	0.00	**0.01 (0.39)**

* Significant difference: $p < 0.05$ between pre- and post-training values; § significant difference: $p < 0.05$ between RS and NRS-groups; RS = resisted sprint; NRS = non-resisted sprint. SJ = squat jump, CMJ = countermovement jump; F_{peak} = force peak; H_{peak} = height peak; W_{peak} = power peak.

TABLE 4. Effect of 6-weeks of training on sprint time at 5. 10. 20 and 30 m (mean ± SD).

Parameter	RS				NRS				ANCOVA p-value (η^2)
	Pre-training	Post-training	Delta %	Cohens'*d*	Pre-training	Post-training	Delta %	Cohens'*d*	
0–5 m (s)	1.11 ± 0.10	1.04 ± 0.05*§	-6.31	0.70	1.17 ± 0.16	1.18 ± 0.13	0.85	0.06	**0.03 (0.32)**
0–10 m (s)	1.92 ± 0.11	1.81 ± 0.09*	-5.73	1.00	1.92 ± 0.14	1.92 ± 0.19	0.00	0.00	0.14 (0.16)
0–20 m (s)	3.23 ± 0.16	3.15 ± 0.14	-2.48	0.50	3.22 ± 0.14	3.17 ± 0.14	-1.55	0.36	0.50 (0.04)
0–30 m (s)	4.50 ± 0.22	4.41 ± 0.18*	-2.00	0.41	4.47 ± 0.18	4.41 ± 0.17*	-1.34	0.33	0.62 (0.02)

* Significant difference: $p < 0.05$ between pre- and post-training values; § significant difference: $p < 0.05$ between RS and NRS-groups;

TABLE 5. Effect of 6-weeks of training on kinematic parameters (mean ± SD).

	RS				NRS				ANCOVA p-value (η^2)
	Pre-training	Post-training	Delta %	Cohen's *d*	Pre-training	Post-training	Delta %	Cohen's *d*	
Stride Frequency (Hz) (stride/second)	4.04 ± 0.21	4.20 ± 0.27*§	3.96	0.76	4.10 ± 0.31	4.07 ± 0.31	-0.73	0.10	**0.01 (0.60)**
Stride Length (m)	1.65 ± 0.08	1.65 ± 0.09	0.00	0.00	1.65 ± 0.12	1.67 ± 0.11*§	1.21	0.17	**0.01 (0.40)**

* Significant difference: $p < 0.05$ between pre- and post-training values; § significant difference: $p < 0.05$ between RS and NRS-groups

to the NRS group (-6.3% vs 0.85%, respectively). Significant post-training improvements at 0–10 m (-5.73%; ES = large) and 0–30 m (-2.00%; ES = small) were detected in the RS group, while the NRS group improved the 0–30 m sprint time performance (-1.34%; ES = small, Table 4).

Kinematic parameters

ANOVA revealed a significant group × time effects for the stride frequency ($F = 20.28$; $p < 0.001$; η^2 = large) and length ($F = 9.10$; $p < 0.01$; η^2 = large). Significant effects in the stride frequency ($p < 0.001$; η^2 = large) and length ($p < 0.01$; η^2 = large) were observed between the two groups at post-testing. A higher stride frequency was found in the RS group (+3.96%; $p < 0.05$; ES = large) compared to the NRS group (-0.73%; $p > 0.05$; ES = small). In contrast, the NRS group was found to have greater stride length (1.21%; $p < 0.05$; ES = small) in comparison to the RS groups (0.01%; $p > 0.05$; ES = marginal). (Table-5)

Receiver operator characteristics

Resisted sprint training with partner towing was significantly more effective in the post-test than non-resisted sprint in the development of short sprint, explosive force, and stride frequency in young soccer players. The area under the receiver operator characteristics [34] curve was > 0.70; $p < 0.01$. The sensitivity was 85–100% and the specificity 89–100%

DISCUSSION

The aim of this study was to evaluate RS vs NRS training and the potential differential effects on leg explosive force, sprint performance and sprint kinematic parameters (stride length and frequency) during a 30 m sprint test in young elite soccer players. The most important findings of this study were that the RS group significantly improved 0–5 m, 0–10 m and 0–30 m sprint performance, leg power and stride frequency, while the NRS significantly increased 30 m sprint performance and stride length.

The results of vertical-jump (SJ and CMJ) and horizontal-jump tests (5JT) showed a significant improvement in all power-related parameters only for the RS group: absolute force and relative force of legs in SJ (4.08%, 4.71%, respectively), vertical-jump height (4.23% in SJ, 3.59% in CMJ) and the 5-jump test horizontal jump distance (3.10%). These results are consistent with those of previous research [30, 37] reporting that explosive-force parameters of the lower limbs improved following resisted sprint training. These results may highlight the efficiency of RS training for improving lower-limb explosive power when in-season short sprint performance improvements are targeted to be maintained or increased. This is especially noteworthy as such fitness measures usually detrain during the in-season.

Of interest was the effect of the two training programmes on sprint performance, which was dissimilar. The RS group significantly improved in 0–5 m and 0–10 m performance by 5.73% while no improvement was observed in the NRS group (0.01%). Conversely, the NRS group improved in 0–30 m sprint performance by 1.34% ($p < 0.05$) while no significant improvement was observed in the RS group for this distance. These results concur with previous literature highlighting that RS training significantly improves short sprint distance performance [12, 38]. Previous studies also suggested that sled towing may provide a superior training stimulus for sprints over short distances [11, 13]. For example, the results of this study are in agreement with those of Zafeiridis et al. [30], who found that an 8-week resisted sprint training programme with a different technique ([5 kg loaded by sled towing], 3 sessions per week), significantly improved performance during the acceleration phase (0–10 m and 0–20 m), without affecting the maximum-velocity phase (20–50 m). The similarities in results between the present study and those of Zafeiridis et al. [30] prove the effectiveness of the partner-resisted sprint training in the enhancement of velocity and speed performance in soccer players. Speculatively, the resistance training performed by the RS group may have acted as a preloading stimulus [39], inducing post-activation potentiation (PAP) during the sprints with chronic exposure leading to greater training responses [11]. It needs to be noted that the observed improvements in the RS group could also have occurred due to the training duration difference in addition to the loading. Although the sprint training programme standardized sprinting distance, the RS group spent more time sprinting training (~4 min over the 6 weeks of training) due to the partner resistance. Future studies are required to determine an appropriate training modality of this style of training, especially the resistance intensity and the rest time between sprint repetitions and sets.

Conversely to the present study, Luteberget al. [40] found no difference between RS and NRS training groups for 30 m sprint time, with a better performance in the NRS trained group compared to RS over a 10 m sprint distance. In that regard, West et al. [11] found that resisted sprint had a more pronounced effect than non-resisted trained groups and suggested that others, who have found that RS is no more effective than NRS sprint training, used too light loads. In this context, Bachero et al. [41] suggested that to improve the initial acceleration, high loads (~20% of BM) should be used, and to improve high speed, low and medium loads (5% and 12.5% of BM) were more effective.

On the other hand, results relating to the acceleration phase in the present study coincide partially with those of Spinks et al. [37], who found significant improvements in acceleration phase (0–5 m, 5–10 m, 10–15 m and whole 0–15 m) after 8 weeks of RS training (twice a week). The latter authors also found that NRS training improved sprint time over 0–15 m. They therefore concluded that the RS training was no more effective than NRS to improve performances of the acceleration phase. Such a difference between the results of the present research and the study of Spinks et al. [37] may be due to the age of the participants and their sport. Indeed, the average age of participants in this study was ~17 years while participants in the study of Spinks et al. [37] were ~22 years. We speculate that the age of the athletes might have an effect on the effectiveness of the resisted sprint training, and this warrants further investigations. Furthermore, Spinks et al. [37] studied participants from 3 different team sports. In that regard, it is of importance to mention that not all the sprints are similar. For instance, the initial phase of a sprint of a soccer player (who usually starts the sprint from a standing position) is very different from that of a sprinter (who starts the sprint, and therefore accelerates, from a much lower position due to the use of starting blocks). This explains why in the present study the sprint assessments were performed from a standing starting position. Therefore, this difference in sports specificities results in completely different technique for the acceleration phase. Such differences should be taken into account when comparing studies having involved different athletes and techniques, and might also be an influencing factor when comparing soccer players from different field positions (defenders, midfielders and attackers, for instance) [42, 43].

The acceleration phase depends on a powerful extension of the leg muscles, while the maximum speed phase depends on the movement speed [44]. In general, resisted training seems to improve lower-limb strength, reactivity and sprint performance [45]. Improving maximal power allows for greater force production in the legs, resulting in a reduction of ground contact time and a possible increase in stride frequency [46].

From the results of this study, it appears that the improvement in sprint performance in the acceleration phase after RS training is the result of a significant increase in stride frequency (3.96%), with no concomitant significant increase in stride length. These results are in accordance with those of Zafeiridis et al. [30], who reported that RS training increased stride frequency while stride length remained unchanged. There are several theories providing plausible explanations for the improvement of the stride frequency after resisted sprint training in the acceleration phase. One of these theories is the increase of the trunk angle during the acceleration phase [30]. Following the model demonstrating the possible contribution of kinematic parameters to running velocity, changes in trunk angle may have an influence on stride length through its effect on the centre of mass of the foot and the centre of mass of the body [47]. Accordingly, the increase in the stride length during the acceleration phase that was expected would be suppressed and the possible reinforcement of the hip and knee muscles would be transferred to increasing stride frequency.

It should also be noted that the participants of this study were not elite sprinters but rather soccer players and that probably NRS training resulted in an improvement in sprinting technique of this cohort. In that regard, powerful and coordinated arm movements are deemed to be essential in promoting forward drive during the entire sprint cycle [48] and critically important during the initial acceleration phase [48]. The horizontal acceleration of the arm swing is believed to also impact stride length, showing that any change in arm movements during sprinting could impact sprinting kinematics. In that regard, it has been demonstrated in several other research studies that non-elite sprinters improved their maximum speed-phase performance after sprint training by increasing the stride length, and rarely by increasing the frequency [48]. This was further supported by Mero and Komi [46], who stated that only elite sprinters improve their sprint performance after sprint training by increasing their stride frequency.

The reader needs to be aware of some limitations associated with this study: (a) The nature of partner towing makes the measure of the resistance difficult (it may be interesting to use a valid dynamometer to assess the intensity of pulling and pushing force). This is the case for many examples associated with the human body and movement. However, we still report and write about their influence. For example, the actual loading that incorporates the frictional forces of resisted sled pushing and pulling is not reported, but there is a large body of literature published in this area that reports the influence of this type of loading on sprint times. Similarly, the air resistance effects of parachute running are not quantified, yet their contribution to understanding sprint overload has been published. However, if we look past this limitation, we think this study has a lot to offer the reader and, in some way, might stimulate readers/scientists to develop technology that allows measurement of these forces. This will take a lot of innovation and prototyping as well as testing the validity and reliability of such technology, which was certainly outside the scope of this article. Nevertheless, in the present experiment, practice with the players has shown that couples of players adapted to each other well and the calibration of resistance (described in the manuscript) was achieved very quickly and no major issues were noted on this aspect of the experiment. The authors of the present study would like to emphasize some important aspects of partner towing that are not possible during sled-resisted sprinting. Not only could sled use damage the soccer pitch but, most importantly, partner towing seems promising from several points of view, including (i) the possibility to start a sprint with resistance and then release the player for free sprinting, as it has been done in the present study; (ii) the possibility to apply 'varying resistance' with multiple possibilities of varying the load and format of exercises. Regarding the load during partner towing, future experiments should consider assessing the force with adapted dynamometers and estimate the working intensity taking into account the body mass and height of both trainee and partner. Obviously, all these potential techniques deserve more research.

Further studies are therefore required to define the optimal load and volume for partner-towing training depending on the specific components of sprint performance to be enhanced and obviously also taking into account the sport-specific sprinting technique.

CONCLUSIONS

Short-term (i.e., 6-week), resisted sprint training with partner towing conducted twice per week induced significant performance improvements in measures of sprint times (0 to 30 m but also 5 and 10 m split times), stride frequency and lower-limb explosive force in young soccer players. However, improvements in 0–30 m sprint times and stride length were also seen when employing a sprint training programme without resistance. Hence, it is suggested that (i) RS training with partner towing be appropriately periodized in young soccer players' training programme to ensure optimal sprint performance gains and (ii) more research be performed on this type of training.

Practical applications

Resisted sprint training in the form of partner towing for speed over short distances has been shown to increase the initial sprint performance (0–10 m). Also, the current findings suggest that this training modality would appear to ensure improvements in lower-limb explosive force and affect the average stride frequency. Coaches should focus on specific sprint training, especially resisted sprinting protocols, to enhance these physical qualities. We cannot discard the benefits of NRS training due to the fact that it was effective in improving performance in the maximum speed phase 10–30 m and the stride length. However, if coaches wish to improve concurrently the speed and explosive force of their soccer players, they could add on in-season RS sessions to ensure short sprint performance improvements in young soccer players.

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Conflict of interest

There are no conflicts of interest concerning this paper.

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