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The effects of resisted training using parachute on sprint performance

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KLIMENTINI MARTINOPOULOU, POLYXENI ARGEITAKI, GEORGIOS PARADISIS, CHRISTOS KATSIKAS, ATHANASIA SMIRNIOTOU

Department of Physical Education and Sport Science, University of Athens

ABSTRACT

The purpose of this study was to examine the effects of resisted and un-resisted sprint training programmes (STP) on acceleration and maximum speed performance. Sixteen sprint athletes divided into two groups (resisted group-RG and un-resisted group-UG, n = 8 each), age 25 ± 4 y, height 172 ± 0.8 cm and weight 61.5 ± 10.6 kg. RG followed the STP towing a large size parachute and the UG followed a STP without resistance. Stride length (SL), stride frequency (SF), contact time (CT) and flight time (FT) were also evaluated. The results showed that the RG improved running velocity (RV) in all sections of acceleration phase (AP), while the UG in the run section 0-20 m. A comparison between groups indicated that RV was significantly higher during run section 0-20 m in the RG compared to the UG. For the maximum speed phase the resisted STP improved the RV in the 40-50 m run section and the maximum speed between 40-47 m, while un-resisted STP had no effect in any run section. SL increased after resisted and un-resisted STP in AP, whereas SF increased only after resisted STP in maximum speed phase. It is concluded that resisted STP with large size parachute significantly improves RV during AP by increasing SL and during maximum speed phase by increasing SF in sprint athletes.

KEY WORDS: *Sprinters, running velocity, stride length, stride frequency, flight time, speed phases.*

INTRODUCTION

Running velocity (RV) is a key factor in the success of most sports as it is the fastest athletes who win the race or any opponent. Running velocity improvement is considered more difficult compared to other physical abilities, such as strength and endurance, as it is also significantly affected by hereditary factors (4, 7, 31, 56). The two factors to affect running velocity are stride length and frequency (16, 22, 30, 32, 43). RV improvement is achieved when either factor is increased with no decrease in the other factor, or when both factors improve (33, 52). Good performance in a run require to start fast as well as achieve and maintain as high a speed as possible, and is divided into secondary phases: acceleration phase, maximum speed achievement, maintenance phase and deceleration phase. Running velocity is affected by a number of factors such as age (38), myofibril type (40), neuromuscular coordination of all limbs in motion (14, 39, 41), muscle architecture (1), strength - power parameters (57). Researchers and trainers have been seeking to develop various training methods to utilise and enhance these hereditary, metabolic and biochemical traits of the human body which may affect the stride length and frequency, resulting thereby in RV improvement (6, 20, 42). The maximum gain with regard to RV is achieved if the training programme is such that induces neuromuscular adaptations (25). The nervous system is stimulated by means of maximum - intensity short - duration training stimuli. The best known training method for RV improvement is repetitive sprint training. The repetitive training method is believed to result in RV improvement during the maximum speed phase (13, 65). Although this method has a positive effect on RV, according to Tabachnik (60) and Ozolin (46), athletes come to a point where they can achieve no further improvement, also known as the "speed barrier" phenomenon. To break the speed barrier, new stimuli are required.

Athletic researchers believe that except for the repetitive training method, good results in RV improvement are achieved by means of strength training (12,15). The means utilised in sprint training with pull against resistance are sled and parachute sprinting. Even though these two methods are similar, they present several differences. With sled towing, resistance is caused by ground friction and exerted on the athlete at an angle, while in parachute sprinting, resistance is applied right behind the athlete's body centre of gravity (BCG) and is caused by the air. It has been suggested that speed training with sled towing helps increase the power output of the hip and knee joint muscles (10, 11, 18, 19, 27, 28). This causes the thrust to increase during sprint stride support, which is essential in order to improve speed during the acceleration phase (9, 34, 58). The parachute method was invented by

Tabachnik (59), according to whom it is ideal for improvement throughout all speed phases (start, acceleration, maximum speed) and also that its use helps bypass the speed barrier (48). A high load on the sled may alter the sprint technique, whereas the parachute method helps ensure that resistance increases with running velocity without any technique alteration (48, 60). The parachute is also indicated for all sports characterised by multiple changes of direction of motion as opposed to the sled which can be utilised in single-direction sports. Other advantages of the parachute: it is easy to carry and the athlete can release the device anytime during practice, thus combining resisted and un-resisted sprint training. Although parachute training is a widely spread training method in various sports, there are not many studies to support the benefit yielded. West (63) has studied the changes in RV kinematics caused by the use of a parachute in comparison with un-resisted running. The study was performed in outdoor track, where major parachute movement was observed and therefore the findings may have been compromised. In addition, LeBlanc and Gervais (29) studied the differences in RV kinematics by using the 'resisted-assisted' method in relation with un-resisted running in various speed phases in track and field athletes. For resistance, a medium sized parachute was used while for assistance (overspeed) a rope-and-pulley overspeed system was employed. Finally, Taylor (61) studied the effects of medium sized parachute training on running velocity in sprinters after a 6 week training programme. The subjects were divided into two groups which followed the same training programme followed twice a week, the only difference being that in the sprint training programme followed twice a week only one team used the parachute. According to the results, running velocity improved in the resisted 55m dash, however, a similar improvement was also observed with un-resisted training. No speed was measured during the acceleration phase and the resisted training programme consisted of 200m run sections, where adaptations are attributed to metabolic rather than neuromuscular adaptations (25).

The aim of this study was to examine the effects of resisted sprint training programs utilising a parachute in comparison with un-resisted sprint training on sprinters during the acceleration and maximum speed phases after a 4-week training period.

METHODS

Subjects: The test group comprised sixteen sprinters, age 20-28 years. Before the study, the subjects had been following the same training programme four times a week. Resisted sprint training is a specialised training method and should be practised by athletes who have managed to maintain a consistent sprinting technique; to this end the participants in the present study had at least four years of athletic training experience. All subjects were informed about the test procedure and signed a written consent form. In addition, they had to abstain from any other athletic activity and medication during the test programme.

The study was conducted during the pre-competitive phase. This specific period was preferred to ensure that the fitness level of the athletes would be satisfactory (strength, speed, endurance, elasticity).

The study plan consisted of three parts: a) initial evaluation testing b) implementation of a 4-week intervention training programme c) evaluation retesting. Participants used spiked shoes throughout the test procedure.

Testing protocol: During the evaluation testing, the running velocity and kinematics of the sprint stride were measured during the acceleration phase and maximum speed phase. Both the initial testing and re-testing took place at the same time of the day in an indoor track stadium, to ensure that the results would not be affected by exogenous factors (wind strength and direction, ambient temperature etc.). Participants used spikes throughout the test procedure. The tests before and after the intervention programme were performed two days after the last training stimulus was given. A recovery period of 24-36 hours is required to achieve full body recovery after a maximum-intensity anaerobic exercise. (3, 36, 60).

The participants were evaluated in a 50m dash and the start begun from a standing crouch position. The run was performed twice (2×50 m) with 5 minute interval and for data processing the best performance was used. This particular run section (50m) was preferred as the optimal distance to achieve maximum speed (8, 12, 44, 49, 51). A 5-minute interval results in full recovery of the participants organic system functions, in order to be able to complete the next trial at maximum intensity (2, 5, 24). Running velocity and performance was measured by photocells in the 0-10 m, 10-20 m, 0-20 m run sections for the acceleration phase (AP) and 20-40 m, 40-50 m, 20-50 m run sections for the maximum speed phase, as well as the maximum speed between 40-46 m. The kinematics of the sprint stride was measured by an optical measurement assembly, capable of recording data for a distance of six metres. The mean of stride length (SL), stride frequency (SF), flight time (FT) and contact time (CT) of the stride were evaluated. Measurements were made between sections 1-7 m and 40-46 m, during the acceleration phase and maximum speed phase respectively, of the 50 m run.

Before the test procedure (initial measurement – re-evaluation), the participants followed the same preparation/warm-up protocol. The warm-up period (duration 30-35 minutes) included: a) moderate running for 8-10 minutes b) stretching exercises for 10-15 minutes and c) sprint specific exercises for 10 minutes. These specific exercises consisted of: a) exercises of kinematic characteristics similar to sprint running and b) 3-4 repetitions of 50-60m runs of increasing intensity. In addition, body height, (cm), body weight (kg) of the subjects were measured, and the Body Mass Index (BMI) were calculated. The body height was measured with millimetre precision and the body weight was determined with a 0.5kgr precision balance (Bilance Salus, Italy).

Running velocity was measured by five electronic photocells (Polifemo radio light-Microgate, Italy). The following kinematic characteristics were analysed: stride length (SL), stride frequency (SF), stride support time (ST) and stride flight time (FT). These kinematic variables were evaluated with Optojump (Microgate, Italy), an optical measurement assembly with measurement accuracy down to 1/1000sec.

Training programme: The resisted sprint training method was adopted. To achieve resistance, a parachute was used (Power Chute^{TM}). The rate of applied resistance should be such that no alteration of the running technique would be observed. Any running velocity decrease $>$10% compared to un-resisted running indicates that the applied resistance load is too high and will have adverse effects on the sprinting technique (10, 25, 53). Based on the above assumptions a pilot study was conducted in order to decide which parachute size should be used. Finally, a large size parachute was used, as the medium size parachute didn't cause any significant resistance.

The subjects were divided randomly into two groups (N = 8 each). Both groups followed the same training programme. The first group followed a resisted training programme with a parachute (resisted group-RG), while the other group used no external resistance (un-resisted group-UG). Resistance in RG group was applied by means of a large sized parachute. The training programme had duration of four weeks and was implemented in the same facility in which the evaluation procedures were held.

The preparation/warm-up protocol throughout the training programme was the same with the protocol that was implemented during the testing procedures. The groups followed the training programme three times a week. The daily schedule (training group) included four repetitions of maximum intensity 30 m & 50 m dashes (4 $\times$ 30 m, 4 $\times$ 50 m). The duration of recovery time between the 30 m & 50 m runs was 4 and 6 minutes respectively. Between the last 30 m dash and the first 50 m dash, a 10-minute recovery was applied. With regard to the frequency and volume of the intervention programme, sprint - speed training is characterised by maximum intensity stimuli to be repeated 2-4 times a week (21). Moreover, sprint - speed training should not exceed 400-500 metres in total (34). To this end, the training programme of the present study consisted of 4x30m and 4x50m runs, at a frequency of 3 times a week. (Total volume = 120 m + 200 m = 320 m). The duration of the recovery time was 4 and 6 minutes for the 30 m and 50 m runs respectively, and 10 minutes between each set. 4-minutes of recovery time is adequate for the body to reach full recovery (2, 5, 24). A recovery time longer than 12 minutes between repetitions in total results in inactivation of the central nervous system (3, 21, 36).

Statistical analysis: A series of t-tests was performed on dependent samples between the initial (pre-) and final (post-) measurement for every analysed variable. For better comparative results, a series of covariance analysis (ANCOVA) was performed, where the values were adjusted by using the initial measurement as a co-variant for every variable. Acceleration phase and maximum speed phase data were analysed separately.

RESULTS

Sample somatometric characteristics are summarized in Table 1.

Table 1. *Sample somatometric characteristics (mean ± SD)*

Somatometric characteristics	Range	Values
Age (years)	20-28	25 (±4)
Weight (kg)	51.0-88.4	61.5 (±10.2)
Height (cm)	162-186	172 (±0.8)
Body Mass Index (kg/m^2)	18.1-25.8	20.8 (±2.4)
Training age	4-8	4 (±1.1)

Sprint speed training with parachute improved performance in run sections 0-10 m ($t = 2.467$, $p = 0.043$), 10-20 m ($t = 3.114$, $p = 0.017$) and 0-20 m ($t = 3.602$, $p = 0.009$) runs respectively, and improved mean speed (Umean) in run sections 0-10 m ($t = -2.722$, $p = 0.03$), 10-20 m ($t = -3.153$, $p = 0.016$) and 0-20 m ($t = -4.427$, $p = 0.003$) (Table 2), while a stride length (SL) increase was also observed ($t = -2.367$, $p = 0.05$).

Table 2. *The results of the training methods in running velocity (RV) and run sections of the stride length (SL) in the accelaration phase*

	Sprint training program with resistance (parachute)		**Sprint training program without resistance**	
variables	**pre**	**post**	**pre**	**post**
0-10 m (sec)	1.74 (±0.16)	1.68 (±0.11)*	1.75 (±0.12)	1.67 (±0.19)
U_{mean} 0-10 m (m/sec)	5.77 (±0.49)	5.96 (±0.38)*	5.71 (±0.39)	6.04 (±0.75)
10-20 m (sec)	1.29 (±0.05)	1.26 (±0.04)*	1.30 (±0.10)	1.32 (±0.15)
U_{mean} 10-20 m (m/sec)	7.71 (±0.32)	7.92 (±0.27)*	7.71 (±0.55)	7.61 (±0.80)
0-20 m (sec)	3.04 (±0.20)	2.94 (±0.14)**	3.06 (±0.21)	3.00 (±0.20)*
U_{mean} 0-20 m (m/sec)	6.58 (±0.41)	6.80 (±0.31)***	6.55 (±0.44)	6.67 (±0.44)*
SL (cm)	135 (±7.4)	142.5 (±10.7)*	140 (±9.4)	147 (±9.3)°
SF (stride/sec)	4.13 (±0.33)	4.29 (±0.21)	4.28 (±0.28)	4.27 (±0.23)
ST (sec)	0.145 (±0.017)	0.148 (±0.016)	0.151 (±0.010)	0.151 (±0.015)
FT (sec)	0.093 (±0.008)	0.086 (±0.010)	0.082 (±0.012)	0.082 (±0.010)

significant difference pre/post the intervention programme:
*** $p < 0.005$, ** $p < 0.01$, * $p < 0.05$, ° $p < 0.1$.

Un-resisted sprint training improved performance ($t = 3.393$, $p = 0.012$) and Umean ($t = -3.174$, $p = 0.016$) in all run sections of 0-20 m (Table 2), and increased stride length (SL) ($t = -2.074$, $p = 0.077$).

Sprint training with parachute improved performance and U_{mean} in run sections 40-50 m ($t = 3.073$, $p = 0.018$ and $t = -2.910$, $p = 0.023$ respectively), and also increased maximum instant speed ($U_{instant}$) between 40-46 m ($t = -2.932$, $p = 0.022$) (Table 3). With regard to sprint stride kinematics, an increase in stride frequency (SF) ($t = -2.062$, $p = 0.078$) and decrease in total duration of sprint stride (SPD) ($t = 2.041$, $p = 0.081$) was observed which is attributed to decreased flight time (FT) ($t = 2.784$, $p = 0.027$), as support time (ST) remained unchanged (from 0.111 ± 0.016 sec to 0.010 ± 0.015 sec).

Table 3. *The Results of the training methods in running velocity (RV) and run sections of the stride length (SL) in maximum speed phase*

	Sprint training program with resistance (parachute)		Sprint training program without resistance	
variables	pre	post	pre	post
20-40 m (sec)	2.28 (±0.10)	2.32 (±0.15)	2.42 (±0.23)	2.45 (±0.20)
U_{mean} 20-40 m (m/sec)	8.75 (±0.41)	8.62 (±0.52)	8.30 (±0.77)	8.19 (±0.67)
U_{mean} 40-46 m (m/sec)	8.74 (±0.53)	8.94 (±0.59)**	8.58 (±0.71)	8.61 (±0.68)
40-50 m (sec)	1.25 (±0.10)	1.21 (±0.10)**	1.25 (±0.14)	1.23 (±0.08)
U_{mean} 40-50 m (m/sec)	8.02 (±0.62)	8.30 (±0.68)**	8.05 (±0.84)	8.11 (±0.57)
20-50 m (sec)	3.54 (±0.19)	3.53 (±0.23)	3.68 (±0.29)	3.69 (±0.27)
U_{mean} 20-50 m (m/sec)	8.49 (±0.47)	8.51 (±0.54)	8.19 (±0.67)	8.16 (±0.60)
SL (cm)	209.5 (±19.3)	205.5 (±18.0)	196.8 (±12.9)	196.1 (±15.1)
SF (stride/sec)	4.17 (±0.363)	4.36 (±0.25)*	4.26 (±0.23)	4.28 (±0.22)
ST (sec)	0.111 (±0.016)	0.110 (±0.015)	0.122 (±0.014)	0.121 (±0.011)
FT (sec)	0.131 (±0.007)	0.119 (±0.006)**	0.113 (±0.012)	0.113 (±0.017)
SPD (sec)	0.242 (±0.022)	0.230 (±0.013)*	0.235 (±0.013)	0.234 (±0.012)

significant difference pre/post the intervention programme:
** $p < 0.05$, * $p < 0.1$.

The results showed that un-resisted sprint training had no significant effect on RV or sprint stride kinematics during maximum speed phase (Table 3). Sprint training with parachute improved performance in run section 50m ($t = 5.267$, $p = 0.001$), and U_{mean} in the same run section ($t = -5.308$, $p = 0.001$), whereas un-resisted sprint training had no significant effect on either performance or U_{mean} in run section 50 m.

The results of ANCOVA analysis showed that after the values were adjusted, performance improvement was higher with resisted training (parachute) 0-20m compared to un-resisted training ($F_{(1, 12)} = 5.307$, $p = 0.04$). The same result was observed with U_{mean} in 0-20 m ($F_{1, 12} = 3.839$, $p = 0.074$) (Figure 1., Figure 2.). Homogeneity of variance was evaluated by the Levene test. The results showed that variances were equal in both performance ($F_{(1, 14)} = 0.012$, $p = 0.913$) and U_{mean} ($F_{(1, 14)} = 0.03$, $p = 0.864$) in 0-20 m.

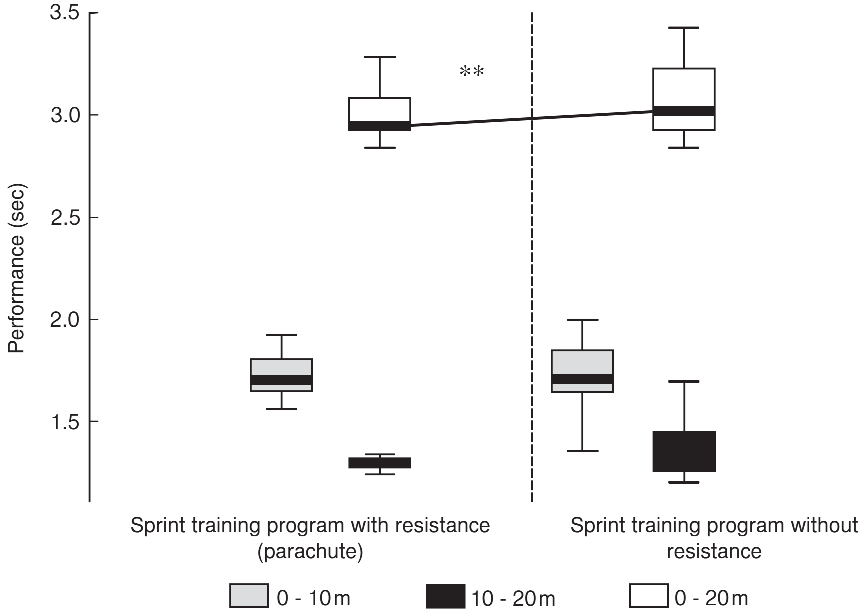

Figure 1: *Performance comparison of the two sprint training methods in run sections 0-10 m, 10-20 m and 0-20 m: ** significant difference, p < 0.05.*

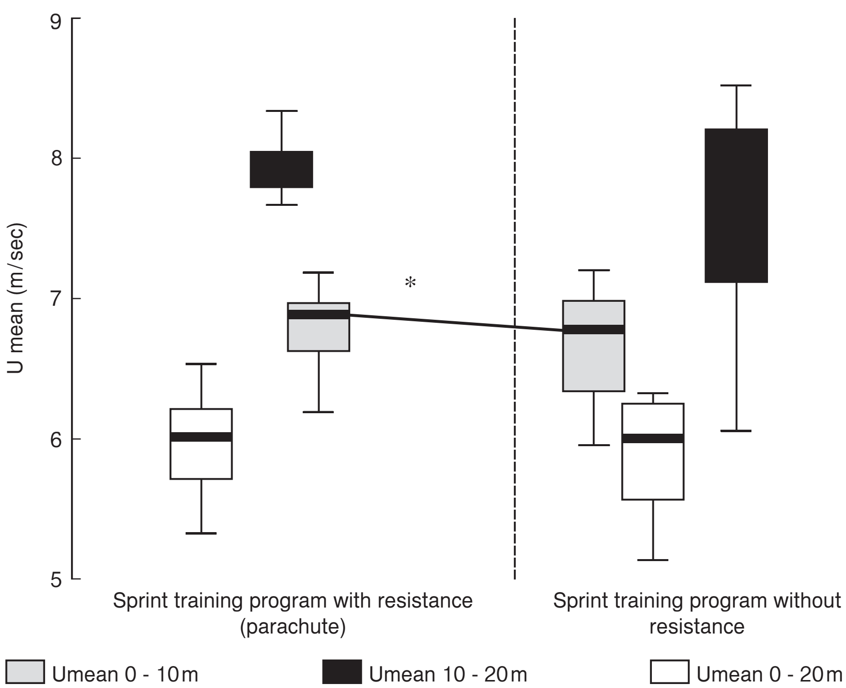

Figure 2: *Comparison of the two sprint training methods for moderate speed in run sections 0-10 m, 10-20 m and 0-20 m: * significant difference, p < 0.01.*

The results of ANCOVA analysis showed that after the values were adjusted, the maximum instant speed ($U_{instant}$) improved further between 40-46 m ($F_{(1, 12)} = 3.448$, $p = 0.088$) (Figure 3). The Levene test results demonstrated that variances are equal (homogeneity) ($F_{(1, 14)} = 0.728$).

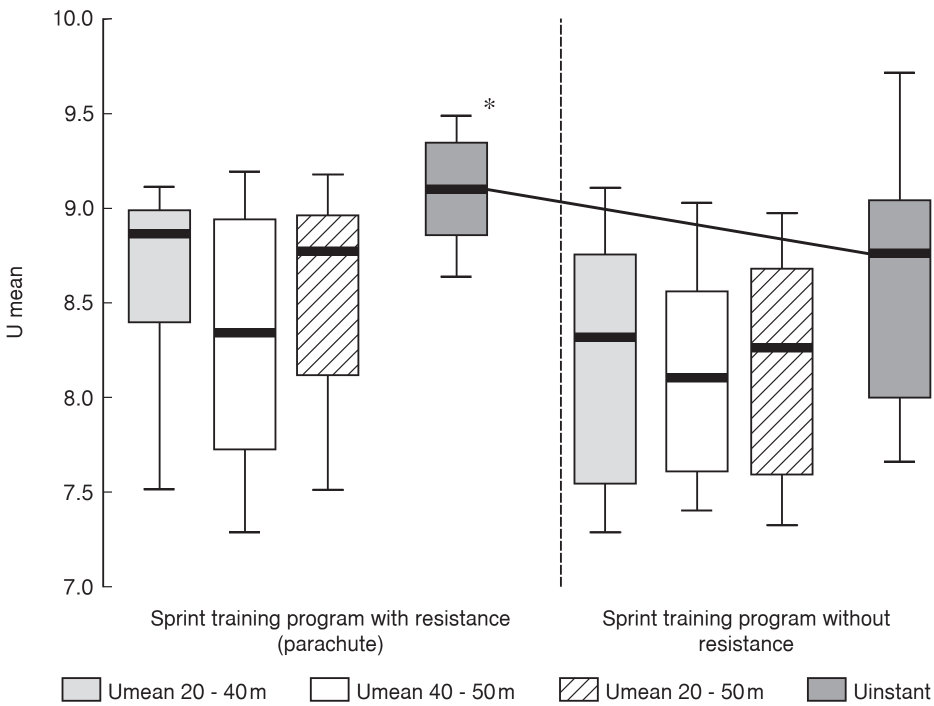

Figure 3: *Comparison of the two training methods for moderate speed in run sections 20-40 m, 40-50 m and 20-50 m and maximum instant speed between 40-46 m: * significant difference, $p < 0.01$.*

DISCUSSION

Resisted speed training with parachute improved speed in the acceleration phase. Running velocity improvement in 0-20 m run is attributed to the improvement of speed in 0-10 m run and 10-20 m run. Sprint-speed training with pull against resistance results in RV improvement by increasing stride length (SL) (10, 11, 17, 18, 19, 50). This is based on the fact that resistance helps increase the power output of the hip and knee joint muscle groups which furthers increases thrust and stride length, a prerequisite to improve speed in the acceleration phase. (9, 33, 34). The findings of the present study coincide with the views of researchers, as sprint speed training with pull against resistance (parachute) improved running velocity in the acceleration phase due to the increased stride length, while no significant change in stride frequency was observed. The SL increase confirms the study assumption that resisted sprint training with parachute modifies sprint stride kinematics. LeBlanc and Gervais (29) have studied kinematic changes observed when using a parachute during maximum intensity sprint running, and have demonstrated that the kinematics of resisted running with parachute is similar to un-resisted running in the acceleration phase.

In the non-resistance group no running velocity improvement was observed in 0-10 m and 10-20 m runs, however, running velocity improved in all sections of 0-20 m run. These results contradict the finding of previous studies, which showed that un-resisted speed training had no effect on RV in the acceleration phase (26, 52, 65). The different results are probably explained by the different samples used and the lack of 'specific strength' of the subjects, which is required for speed improvement in the acceleration phase (13). Rugby athletes yielded similar results, where un-resisted sprint speed training had no effect on speed during the acceleration phase (26).

Resisted sprint training with parachute improved running velocity more than un-resisted sprint training in the 0-20 m run section. As reported in the literature, training with pull against resistance has better results on speed in the acceleration phase, compared to un-resisted sprint training (26, 52, 65). A sled was used as a means of pull against resistance in the afore-mentioned studies, whereas for the purposes of the present study a parachute was used. In the current study the athletes of both groups improved running velocity in the 0-20 m run section, however in the group that followed the resisted training programme (parachute) a bigger improvement in running velocity was observed. These data agree with the views of researchers according to which pull against resistance is a specialised training method (17, 55, 60, 64) in terms of both motion and sprint speed. Therefore, when applied it results in better training adaptation to speed, compared to other training methods (23, 45, 66). Although no RV improvement was observed in the 20-40 m run section or in all sections 20-50 m, an improvement was observed in 40-50 m run section and maximum speed between 40-46 m, thus confirming that resisted sprint training (parachute) improves RV in the maximum speed phase. The results of the study agree with the view that opts for a parachute in training, as the parachute is also suitable to increase RV in maximum speed phase (60).

Resisted sprint training (parachute) yielded a sprint stride duration decrease, due to flight time decrease, while support time remained unchanged. The decrease in the duration of sprint stride helped increase stride frequency (SF) (from 4.17 ± 0.36 stride/sec to 4.36 ± 0.25 stride/sec), given that stride length (SL) remained unchanged. These findings agree with studies according to which further velocity improvement in higher speed is achieved when SF increases, while SL remains unchanged (30, 37, 41). In fact, sprint stride kinematics were analysed between 40-46 m where the observed instant velocities ranged within 8.94 ± 0.59 sec. The FT decrease and SF increase confirm the study assumption that resisted sprint training with parachute modifies sprint stride kinematics. Un-resisted sprint training did not improve running velocity in the maximum speed phase. The results yielded from various researches about the specific training method are contradicting. Although this specific training method is applied in order to improve velocity during maximum speed phase (13, 52, 62, 65), there have been studies where no improvement was observed (26, 47, 50). These divergent conclusions are likely due to differences in the level of training between the subjects employed in the study and the fact that the subjects were not sprinters. Other researchers support that if the same training programme is followed constantly, the athletes reach a plateau (speed barrier), thus no further velocity improvement is achieved (3, 46, 60). The method of repetitive training (un-resisted) is usually applied to sprinters. Therefore, the lack of velocity improvement may be due to the fact that the same training method was also implemented in the intervention programme.

The group that followed the parachute training programme improved velocity by 3.5% in the 40-50 m run, while the un-resisted training group presented a minor velocity increase of 0.7%. All 8 participants of the 'parachute group' improved their velocity in the run section 40-50 m (100%), while an increase was observed only in 4 out of 8 (50%) subjects in the un-resisted group. The co-variance analysis (ANCOVA) did not ascertain that resisted sprint training (parachute) brings better results compared to un-resisted sprint training. This may be due to the significant difference in the variance of values between the initial and final measurement in the un-resisted group. However, the comparative results indicated that sprint training with parachute resulted in a significantly higher RV between 40-46 m, compared to un-resisted sprint training in the maximum instant speed phase between 40-46 m. It is evident that resisted sprint training (parachute) brings better results in terms of RV improvement compared to un-resisted sprint training. The duration of the programme (4 weeks) was possibly not adequate to further improve maximum speed. Resisted sprint training with parachute improved RV in all run sections of 50m, while no improvement was observed in the un-resisted group. The improvement seen in all run sections of 50 m in the resisted (parachute) group is attributed to the improvement in the acceleration phase and maximum speed phase, whereas the un-resisted group only improved in the acceleration phase with no effect in the overall performance in the same run section. All 8 participants of the “parachute group” improved their performance in the run section 50 m (100%), while only 6 out of 8 subjects improved their performance (75%) in the un-resisted group.

CONCLUSION

Resisted sprint training with large size parachute improved velocity in the acceleration phase and maximum speed phase in sprinters, while un-resisted training resulted in no significant improvement.

Compared to other means of pull against resistance used to improve velocity in the acceleration phase, the parachute appears to be a suitable training method for velocity increase in the maximum speed phase.

When sprint speed training with parachute is included in a training programme, which is designed to improve sprint technique, it can improve both stride length and stride frequency.

The mechanisms responsible for velocity improvement and the long-term results of including the parachute in a sprint speed training programme should be further investigated.

Finally, compared to other means of pull against resistance, the parachute may also be employed in sports characterised by multiple changes of direction of motion where speed is a key parameter. The suitability of resisted sprint training with parachute in other sports may be investigated by recruiting the suitable athletes.

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Address for correspondence:

Polyxeni Argeitaki
Ethnikis Antistaseos 21, Daphni
17237, Athens
Greece
E-mail: pargeit@phed.uoa.gr