Original Article

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Optimizing the load for peak power and peak velocity development during resisted sprinting

Aleksander Matusiński [1ABCD], Artur Gołaś [2ABD], Adam Zając [2ABDE], Magdalena Nitychoruk [1ABCD], Adam Maszczyk [2ABDE]

[1] Department of Sport Theory, The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland
[2] Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland

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Abstract

Introduction: Resistance towing is perhaps the most specific form of developing strength and power in muscles involved directly during the start, acceleration and at maximum speed. Resisted sprint training may involve towing a sled which provides an overload through the friction between the sled and ground surface or a modern advanced training device which uses drag technology to provide fully controlled resistance during the movement, such as the 1080 Sprint. The main objective of the study was to evaluate the optimal loading for the development of power in the engine assisted drag technology system SPRINT 1080. *Material and methods:* We evaluated the changes in running velocity and the generated force and power during resisted sprints over 30m with a load of 1, 3, 6, 9, 12 and 15 kg. Seven male sprinters with national and international experience participated in the study. Their average age, body mass and body height were 22.2 ± 2.4 years, 77.43 ± 4.63 kg, and 178.6 ± 3.2 cm, respectively. All athletes performed six 30 m sprints with 5 min rest intervals in between. The first sprint was performed without additional resistance, while the remaining 5 were performed in an random order with additional resistance of 3, 6, 9, 12 and 15 kg. After receiving a verbal signal, the participant started at will from a semi crouched position. During the resisted sprint trials, the time [s] and the following variables were recorded in peak values: power output [W], generated force [N], and sprinting velocity [m/s]. *Results:* Our results show that loading with 6 kg decreased sprinting velocity by 9.37% while the generated horizontal power increased by 31,32%. The 6 kg loading on the Sprint 1080device corresponded to 8% body mass, yet as mentioned before the baseline results were not fully free sprinting as the tested athletes reached velocities 0.5-0.6 m/s greater without the harness. *Conclusion:* Taking into account this fact, our results seem to confirm previous findings, that external loads between 8 and 13% may be optimal for improving power and sprinting speed at the same time.

Keywords: developing strength, muscle power, sprint training, sprinting speed

Address for correspondence: Magdalena Nitychoruk - The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland. Institute of Sport Sciences, e-mail: magda.aneta.krawczyk@gmail.com

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INTRODUCTION

Considering the available training interventions for sprinters, resistance exercises seem to be most effective in inducing both, acute and chronic enhancement of sprinting performance. Resistance exercises programed for improving sprinting speed include locomotor activities and fixed plane resistance exercises, such as jump squats and different variations of the clean and jerk and the snatch [1,2]. Examples of resisted sprint training include towing, weighted vests, uphill sprinting, and sprinting in sand or water [3]. However the most often used, and most effective form of resistance sprint training includes towing [4]. Resisted towing has proven effective in improving both acceleration and maximum sprint speed. It is assumed that resisted sprint training allows more muscle fibers to be recruited via greater neural activation and results in improved stride length [5]. Resistance towing is perhaps the most specific form of developing strength and power in muscles involved directly during the start, acceleration and at maximum speed. Resisted sprint training may involve towing a sled which provides an overload through the friction between the sled and ground surface or a modern advanced training device which uses drag technology to provide fully controlled resistance during the movement, such as the 1080 Sprint [6-8]. Acute sprint sessions have shown the effectiveness of towing in enhancing physical output and sprinting efficiency compared to unresisted sprinting [7,9-10]. From a practical point of view, the main objective for scientists and coaches is to determine the optimal load for each athlete during resisted towing. The objective is to find such a load for towing that allows to generate the greatest power output without compromising running velocity and sprinting mechanics. Resisted sprint training with sled loads ranging from 12 to 43% body mass have been shown to be effective in improving sprint performance in trained individuals [11]. Using very low loads (5 kg) during towing results in the generation of low values of power, and insignificant improvements in acceleration [12], while excessive loading may alter sprint kinematics by increasing ground contact, decreasing stride length and limiting hip extension [5,13]. Towing may have a greater impact on starting speed and acceleration than on maximum sprint speed, yet sprint adaptations may be velocity specific [11,14]. It seems that heavy sled loads (≥20% BM) enhance initial acceleration where velocity is low and resistance forces are high. On the other hand, light sled loads (≤10% BM) may improve maximum running speed, where velocity is very high and resistance forces are low [11]. Considering the above, sprinters should experiment with different loading during towing, to enhance power development, the acceleration phase as well as the maximum velocity phase. It seems that loading should be individualized, depending on the strength potential of the athlete, while towing distance should vary from 10m to 40-50 m depending on the training objective [4].

Considering the effectiveness of resisted sprint training, and the acute enhancement of sprinting performance through locomotor exercises, we decided to evaluate the optimal loading for the development of power in the engine assisted drag technology system SPRINT 1080. We evaluated the changes in running velocity and the generated force and power during resisted sprints over 30m with a load of 1, 3, 6, 9, 1 and 15 kg. The main objective of the study was to evaluate the optimal loading for the development of power in the engine assisted drag technology system SPRINT 1080.

MATERIAL AND METHODS

Participants

Seven male sprinters, members of an academic sports club participated in the study. The research was carried out on an indoor synthetic track to avoid the influence of weather on results. The participants were experienced sprinters (7.2 ± 1.4 years training experience) that competed at the national and international level at distances from 100 to 400 m. Their average age, body mass and body height were 22.2 ± 2.4 years, 77.43 ± 4.63 kg, and 178.6 ± 3.2 cm, respectively. The participants did not perform any strenuous exercise 48 hours prior to testing to avoid fatigue. The participants were informed verbally and in writing about the procedures, possible risks and benefits of the study, and provided written consent before the commencement of the study. Moreover, they were asked to maintain their normal dietary and sleep habits throughout the study and not to use any supplements or stimulants for 24 h prior to testing. The study received the approval of the Bioethical Committee of the Academy of Physical Education in Katowice (10/2018), and was performed according to the ethical standards of the Declaration of Helsinki.

Procedures

During particular sprints, the SPRINT 1080 engine assisted measuring system (1080 Motion AB, Stockholm, Sweden) was used for the precise selection of loads and variables, adapted to the diagnostics of sports training and performance [8]. The system uses changing intelligent drag technology to provide fully controlled resistance in the resisted and assisted phases of the movement. The device can record running time with an accuracy of 0.01s and the average and peak values of such variables as force [N], power output [W] and velocity of a moving athlete [m/s]. The device has the option of changing setting of the resistance expressed in [kg] in all phases of the sprint. According to the data reported by the manufacturer, the system shows high repeatability and accuracy for measuring position (≤ 0.5%), velocity (≤ 0.5%), and force (≤4.8 N) [15].

The evaluations were carried out in an indoor athletics facility on Monday, following two days of rest to ensure maximum effort from the athletes. To avoid the influence of weather conditions (wind, temperature etc.) on performance, the tests were performed on an indoor synthetic track. All evaluations were performed at the same time of the day, between 10:00 and 12:00 am. to avoid the influence of circadian rhythm on performance. Three days before the main testing the athletes were familiarized with the experimental protocol, and performed 3-4 loaded sprints with the resistance ranging from 1 to 20% body mass. On the same day they were subjected to anthropometric measurements (height and body mass). The participants used their track spikes during the resisted sprint exercise protocol. The research protocol was preceded by a standardized, sprint specific warm-up (30-35 min) that was consistent with participants normal training habits. All athletes performed six 30m sprints with 5 min rest intervals in between. The first sprint was performed without additional resistance, while the remaining 5 were performed in an random order with additional resistance of 3, 6, 9, 12 and 15 kg. After receiving a verbal signal, the participant started at will from a semi crouched position. During the test, the participants were connected to the SPRINT 1080 measuring device with a light belt fastened around the hips, so that their movements were not restricted in any way. The SPRINT 1080 was placed and firmly attached to the ground approximately 2m behind the starting line. The method of mounting the device and the connection with the tested participant through the harness and cable caused that the vector of the drag force was directed exactly parallel to the ground and opposite to the running direction. During the resisted sprint trials, the time [s] and the following variables were recorded in peak values: power output [W], generated force [N], and sprinting velocity [m/s]. Despite no additional load the free sprint had an resistance of approximately 1 kg, considering the weight of the belt the athletes were fastened with, and the cord, through which the resistance was provided.

Statistical analysis

All variables were expressed as mean or median ± standard deviation (SD). Before using a parametric test, the assumption of normality was verified using the Kolmogorov-Smirnov test. The distributions of all variables were normal or close to normal. The numbers of quality data for analyzing groups were obtained using analysis of contingency table.

The one-way ANOVA was used with significance set at $p<0.05$, to determine differences between loads, velocity and power variables. When appropriate, a Tukey post hoc test was used to compare selected data, and the effect of each test was calculated to determine the significance of the results. The relative single-base and chain increments were determined on the basis of time series. The remaining analyses were performed using STATISTICA (Stat Soft, Inc. version 12).

RESULTS

Table 1 contains results of post hoc tests for one-way ANOVA between loads and sprinting velocity, while table 2 between resistance loads and generated power. One-way ANOVA showed a statistically significant change in speed with an external load of 6, 9, 12 and 15 kg. There was no statistically significant change in sprint speed with an particular loads of 3 kg and the base sprint.

Table 1. Statistically significant differences between particular loads and running velocity after post hoc tests.

Load	1kg	3kg	6kg	9kg	12kg	15kg
1kg	-	0.998	0.001	0.001	0.001	0.001
3kg	0.998	-	0.001	0.001	0.001	0.001
6kg	0.001	0.001	-	0.025	0.001	0.001
9kg	0.001	0.001	0.025	-	0.019	0.001
12kg	0.001	0.001	0.001	0.019	-	0.010
15kg	0.001	0.001	0.001	0.001	0.010	-

Table 2. Statistically significant differences between resistance loads and generated power after post hoc tests.

Load	1kg	3kg	6kg	9kg	12kg	15kg
1kg	-	0.478	0.001	0.001	0.001	0.001
3kg	0.478	-	0.000	0.001	0.001	0.001
6kg	0.001	0.001	-	0.001	0.001	0.001
9kg	0.001	0.001	0.001	-	0.001	0.001
12kg	0.001	0.001	0.001	0.001	-	0.067
15kg	0.001	0.001	0.001	0.001	0.067	-

Table 3. Comparison between sprinting velocity and power in relative single-base increments using the time series in relation to the applied loads.

Loads	Velocity raw data [m/s]	Single-base increments Velocity [%]	Power raw data [W]	Single-base increments Power [%]
1kg	9.09	0	705.29	0
3kg	8.99	-1.04	756.86	7.31
6kg	8.24	-9.37	926.14	31.32
9kg	7.69	-15.44	1143.86	62.18
12kg	7.12	-21.71	1309.00	85.61
15kg	6.51	-28.40	1399.57	98.44

Table 4. A comparison between sprinting velocity and generated power in relative chain increments using the time series in relation to the applied loads.

Loads	Velocity raw data [m/s]	Chain increments Velocity [%]	Power raw data [W]	Chain increments Power [%]
1kg	9.09	0	705.29	0
3kg	8.99	-1.04	756.86	7.31
6kg	8.24	-7.38	926.14	15.06
9kg	7.69	1.72	1143.86	1.14
12kg	7.12	-0.72	1309.00	-9.07
15kg	6.51	-7.92	1399.57	7.92

One-way ANOVA showed a statistically significant change in the generated horizontal power with an external load of 6, 9, 12 and 15 kg. There was no statistically significant change in the generated horizontal power with an external load of 3 kg and the base sprint. Tables 3 and 4 present the comparison between speed and power in relative single-base increments and chain increments using the time series in the aspects of loads. Results show that loading with 6kg decreased sprinting velocity by 9.37% while the generated horizontal power increased by 31,32%. Loading with 15 kg decreased sprinting velocity by 28.40% while the generated horizontal power increased by 98.44 %.

Results show that the 9 kg external load caused a drastic drop in sprinting velocity with a very significant increase in power compared to 6 kg loading (218 W). The 12 kg loading increased the power by 165 W, yet caused a minor decrease in sprinting velocity.

DISCUSSION

During initial stages of sprint training, free sprinting, or training without the use of any external equipment forms the basis of most training programs. As the athletes progress in sports level, they require new forms and methods of training to stimulate additional adaptive changes in the neuro-muscular system [16,17]. To continue improving the physical, metabolic and neurological components essential for increasing sprinting speed, one must use various training methods to improve stride length, stride frequency and reaction time [13]. These modalities may include high speed treadmill sprinting, elastic cord towing, downhill sprinting as examples of overspeed training to increase stride frequency. Stride length and acceleration can be improved in the best way by implementing resisted sprint training, such as sled towing, weighted vest sprinting, uphill sprinting, parachute sprinting, explosive strength training and plyometrics. Recently intelligent drag technology has been introduced into sprint training, which offers numerous benefits [6]. When using a cable resistance device, the load is the same for the entire movement. While in the case of resisted sprint training with the use of the sled, the greatest resistance occurs at the beginning of the movement due to the force needed to overcome the static friction, and then slightly decreases as the force required to continue the movement decreases. Most studies evaluating the effectiveness of resisted sprint training used towing devices [4], while few studies have been conducted with the use of intelligent drag technology, such as the Sprint 1080 [6]. Resisted towing, especially with the drag technology provides resistance throughout the sprinting distance which varies depending on the training objective from 10 to 40-50m. This type of training increases the force output at the hip, knee and ankle, allowing the sprinter to generate greater power during the acceleration phase. Resisted towing can be considered sport specific because it develops the muscles used in sprinting in appropriate movement patterns specific for high velocity running [11,18]. The key variable in resisted towing, that determines the effectiveness of such training modality is the loading used during resisted sprinting. Numerous authors point to the fact that applying an insufficient load may not produce a training stimulus, and excessive loading can significantly slow down the sprinting motion and alter running mechanics. These authors point to the fact that towing very heavy loads increases ground contact, decreases stride length, and limits hips extension, thus altering previously developed movement patterns, or sprinting technique [3,5,19]. Most scientists recommend resistance loads of 10-13% body weight [12,22] for resistance towing, while others suggest that the optimum resistance for towing should not slow down the athletes more than 10%, or else the running velocity should not fall below 90% of the athlete's maximum velocity in a fee sprint [3-4,19]. Most research in sprint running has used a single trial method, due to the inability to express the mechanical output during unresisted sprinting. Thus the novel aspect of this research includes the use of 6 different resistance loads applied in an even progression what allowed to compare the effects of loading on such variables as power, force and running velocity. The limitation of the study is the lack of estimation of maximum running speed and velocity as the harness and cord of the Sprint 1080 device provide about 1kg of resistance and thus maximum velocity wasn't reached. The most important finding of the study is the fact that significant differences occurred in all loaded sprints in sprinting velocity and the generated horizontal power, except for the baseline sprint and the 3kg external load. Otherwise power increased alongside the increase in load reaching almost 1400 W with the external load of 15 kg what equaled approximately 20% body weight. The increased loading caused concomitant drops in sprinting velocity, which reached almost 30% during the highest loading. Considering the recommendations of Alcaraz et al. [3] and Cross et al. [6], which indicate that resisted sprinting loads should not decrease the velocity more than 10%, our results show that loading with 6kg decreased sprinting velocity by 9.37% while the generated horizontal power increased by 31,32% [3,6,21]. The 6 kg loading on the Sprint 1080 device corresponded to 8% body mass, yet as mentioned before the baseline results were not fully free sprinting as the tested athletes reached velocities 0.5-0.6 m/s greater without the harness. Taking into account this fact, our results seem to confirm previous findings [2,4,7], that external loads between 8 and 13% may be optimal for improving power and sprinting speed at the same time. On the other hand the 9 kg external load caused a drastic drop in sprinting velocity with a very significant increase in power compared to 6 kg loading (218W). The 12kg loading increased the power by 165 W, yet caused a minor decrease in sprinting velocity. This may suggest that resisted sprinting has to be individualized, depending on the sports level, strength of the lower limbs and training objective. According to Cross et al. [6], very heavy loads (40-50% BW) can be used over short distances (5-10 m) to produce peak power and improve acceleration. At longer resisted sprints of 30-50 m, a much smaller external load is recommended as in our research, as such loading can improve the athletes acceleration and maximum sprinting velocity at the same time without altering sprinting mechanics.

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