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IMPACT OF SLED LOADS ON VELOCITY DURING ACCELERATION PHASE FROM STARTING BLOCKS

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ABSTRACT

Sprinters use the weighted sled to improve acceleration ability starting with the standing position, but little information is available. The purpose of this study was to examine the effect of sled loads on velocity achieved during a short distance sprint from the starting block and to develop a regression equation to determine the sled load in relation to the body mass (BM). Twenty-two male sprint athletes (age: 21.1±2.2 years; height: 178±6.0cm; body mass: 73.5±9.5kg; competitive experience=6.4±1.0yrs; personal best performance in 100m=11.05±0.27secs) performed five sprints over a distance of 15m from starting blocks on a synthetic surface and with track shoes (loaded conditions: 7%, 10%, 15% and 20% of BM). Sprint time for 15m under the four loaded conditions was significantly lower than the unloaded condition ($p<0.05$). The results led to determining a regression equation to calculate the load that can be used with sled-towing when sprinting from starting blocks (Equation: %BM= -1.48 (% velocity)+148.85). This equation may be an appropriate tool for coaches to optimise training sessions for male sprinters.

***Keywords*:** Equation; Resisted run; Sled training; Starting blocks.

INTRODUCTION

Sprint performance is an essential component for success in most high-level sports. Thus, the development of acceleration and velocity becomes a major issue for coaches and physical trainers to achieve optimum athletic performance. In order to improve the acceleration phase, sprinters must seek to increase the amount of force applied to the ground (Okkonen & Hakkinen, 2013). Along with traditional sprint training, RST (Resisted Sprint Training) represents another method of developing sprint capability. In fact, this method increases the stride length and thus the velocity, as was concluded by Lockie *et al.* (2003), without alteration of proper sprinting technique (Alcaraz *et al.*, 2009).

Regarding the scientific literature, several studies focussed on many forms of RST (sled towing, parachutes and weighted vests). To date, the effectiveness of RST on sprinting performance demonstrated that sled towing still represents the most investigated method (Spinks *et al.*, 2007; Cottle *et al.*, 2014; Cross *et al*., 2017).

From another point of view, towing excessive loads increases the ground contact time, decreases stride length and alters the running (Kawamori *et al.*, 2014). In order to monitor excessive changes in mechanics and velocity, practitioners should behave carefully. In some previous studies (Spinks *et al.*, 2007; Harrison & Bourke, 2009) the appropriate loads recommended in resisted towing were 10%, 12.5% and 13% of BM (Body Mass). Most of these sled towing investigations that focussed on team sports were performed essentially on natural grass (soccer, rugby) (Harrison & Bourke, 2009; Clark *et al*., 2010; Martinez-Valencia *et al.*, 2013; Luteberget *et al*., 2015).

In order to calculate the towing load required in a training session, Lockie *et al*. (2012) and Spinks *et al*. (2007) developed an equation which identified the individual towing load needed to improve the acceleration and the velocity in team sports. However, only few studies focussed on sprinters when towing a weighted sled (Murray *et al*., 2005; Makaruk *et al*., 2013; Martinez-Valencia *et al*., 2013). For example, Lockie *et al.* (2003:3) proposed a regression equation to estimate velocity decrease according to the imposed towing load. This specific equation may be used to optimise the training session for the sprint standing start in field-sport athletes.

$$\textit{Equation}_{\textit{Lockie et al}} : [\%\ BM = (-1.96 \times \%\ velocity) + 188.99]$$

Track and field events, however, require a low starting position using the starting blocks (IAAF, 2017). Furthermore, the performance depends on the quality of the start and acceleration from blocks (Čoh & Tomažin, 2006). Additionally, as mentioned before, the effectiveness of an exercise is in its relation to the characteristics of the practiced sport which remains a determining factor (Behm & Sale, 1993). Therefore, trainers should integrate the sled towing in training sessions starting from blocks in order to enhance the velocity.

In this context, Maulder *et al.* (2008) concluded that a load of 10% and 20% of BM reduced the step length and decreased the velocity by 8% and 15% over a 10m distance. Those authors considered that using resisted sled towing with 10% BM was beneficial for improving the sprint start and early acceleration performance of athletes. This would lead to a better understanding regarding the relation between towing loads and velocity decrease during the acceleration phase from the blocks in order to improve the training programmes.

PURPOSE OF RESEARCH

The purpose of this study was to examine the acute effect of towing loads on velocity achieved during 15m-sprint from starting blocks (Lockie *et al.*, 2003; Alcaraz *et al.*, 2009) and to develop a regression equation allowing the determination of the sled load in relation to the BM in order to control the sprint velocity. Prior to this, a pilot study is required to verify the reproductibility of the equation proposed by Lockie *et al.* (2003) and Alcaraz *et al.* (2009) in track specific conditions.

METHODOLOGY

Pilot study

Eight (8) male track sprinters were volunteers to participate in test sessions. Participants were competitive athletes on national level with experience in sled-tow training and who had not had recent injuries (mean±SD for age: 20±9yrs; height: 1.77±0.5m; BM: 72.4±9.8kg; competitive experience: 6.6±1 years; 100m personal best: 11.09±0.22secs). The sled load corresponding respectively to 7%, 10%, 15% and 20% of BM were calculated after the sprinters were weighed. The VS Compact Wind Gauge (Gill Athletics, Illinois, USA) was used to measure the wind velocity.

To examine the acute effects of sled loads on sprint performance, the participants performed 15m-sprints under five conditions with one trial for each: one unloaded and four loaded conditions (7%, 10%, 15% and 20% of BM respectively) from the standing start without arm support. The velocities achieved in every load condition were expressed in the percentage of the maximum velocity for 15m unloaded condition and were averaged for all subjects (Real Velocity=RV) and then were compared to the percentages of the Estimated Velocity (EV) using the equation proposed by Lockie *et al.* (2003) and validated by Alcaraz *et al.* (2009) for the acceleration phase from a standing start in specific athletics conditions.

Sprint performance, time lost, maximum velocity and percentage of velocity loss of unloaded and all loaded conditions are presented in Table 1. Data are reported as means±standard deviations and confidence intervals at the 95% level. The t-test for related samples was used to analyse the differences between real lost percentage in 15m maximum velocity, and estimated percentage in maximum velocity lost using the equation of Lockie *et al.* (2003). In addition, the delta-percentage ($\Delta_{\%}$) of velocity lost (L1 and L2: "$\Delta_{(\%)} = [(V_1-V_2)/V_1] \times 100$") was calculated in order to evaluate the variation percentage between the different loads.

Table 1. **MEAN±SD 15M-SPRINT PERFORMANCE, LOADS, % REAL VELOCITY, % ESTIMATED VELOCITY, DIFFERENCE BETWEEN EV AND RV**

Variables	Unloaded	7% BM	10% BM	15% BM	20% BM
15m perf (s)	2.38±0.07	2.49±0.09	2.55±0.10	2.62±0.10	2.68±0.12
Loads (kg)	0.0	5.1±0.68	7.3±0.97	11.0±1.45	14.7±1.94
RV (%)	100%	95.5±1.40	93.2±2.74	90.7±2.65	88.9±3.02
EV (%)	100%	93.8±0.34	92.7±0.48	90.8±0.72	88.9±0.97
Difference (%)	----	1.67±1.3*	0.43±2.50	-0.22±2.41	-0.17±2.62
CV (%)	----	1.55	1.81	1.77	1.95
Effect size (*dz*)	----	1.20+	0.16	0.08	0.06

BM= Body Mass RV= Real Velocity EV= Estimated Velocity CV (%)= Variation percentage
* $p<0.05$ + Moderate effect size n=8

Significant differences were not observed between RV and EV in loads corresponding to 10%, 15% and 20% BM conditions. However, significant difference was found in the 7% BM conditions (difference in percentage between RV and EV: 1.67±1.3). Referring to these results, the equation suggested by Lockie *et al.* (2003) and Alcaraz *et al.* (2009) could be considered as a reproducible tool considering the difference between sprinter's performances. The R^2 value for this equation was 0.995, which demonstrated the highly significant relationship between % BM and % velocity.

Experimental approach

In this study the acute effects of four different resistive sled loads on sprint performance executed from starting blocks in male sprinters were examined. The participants (n=22) performed 15m sprints under five loading conditions in the following order : free external resistance, sled weight with 7%, 10%, 15% and 20% of BM. The sprint performance measures were recorded for all participants. The maximum velocities and the percentage of velocities lost related to unload velocity for the 15m-sprint were calculated in order to follow the regression of the velocity when increasing the sled weight.

Subjects

Twenty two male track sprinters (age: 21.1±2.2yrs; height: 178±6cm; BM: 73.5±9.5kg) with national competitive level experience were recruited (100m personal best performance: 11.05±0.27s). The participants were experienced with at least five years of competitive experience (6.4±1.1 years) and they were frequently exposed to sled-training. Moreover, they reported no recent injury. All subjects provided written consent after being informed of the aims, benefits and risks involved with this investigation. This study protocol was approved by the local University Ethics Committee.

Procedures

After determining the anthropometric measures (height and BM) the sled load corresponding respectively to 7%, 10%, 15% and 20% of the individual BM was calculated. Before beginning the testing session, athletes individually placed Polanik starting blocks. Then, a standardised warm-up was presented to the athletes, which included a 10-minute continuous jog at moderate intensity, followed by dynamic stretching exercises for a duration of 10 minutes and 3 short 20m accelerations, followed by two sled-towing accelerations (without added loads). After this warm-up period (and before each sprint), the wind velocity was checked using VS Compact Wind Gauge (Gill Athletics, Illinois, USA). The climate temperature was about 23°C. The sprint was authorised when the wind velocity was less than ±2 $m.s^1$. Each participant performed five 15m-sprints: an unloaded sprint and four loaded sprints (7%, 10%, 15% and 20% of BM).

In order to eliminate the influence of reaction time, the electronic timing gates were placed at 1m, 6m, 11m and 16m from the starting line to record the sprints performance over 15m (between 1m and 16m). Between each sprint, a passive recovery period of at least five minutes was allowed. Considering that the fatigue induced by the total sprints was minimal, the order of the sprint was not randomised (due to a long passive recovery period and the short sprint duration). During the loaded sprints, a 200mm embellished sled was used with 700mm spreading. The sled keeps the same characteristics of the contact surface with the ground as defined by Alcaraz *et al.* (2009) (two parallel metal tubes about 500mm and 30mm in diameter). As the sled weighed 3.6kg, the additional load required on the sled was defined using the following formula:

Equation 1: $\text{Load} = (\text{BM} \times \% \text{ of BM}) \div 100) - 3.6$

The mass of the additional loads used was of 1.5kg, 0.5kg, 0.2kg and 0.1kg. The sled was attached to the athlete by a waist harness and a rope 4m long. Moreover, test sessions were conducted during the pre-competitive period on a tartan track, and all athletes wore tight-fitting clothes and their track spike shoes.

Statistical analysis

Data are reported as means±standard deviations and confidence intervals at the 95% level (95% CI). Normal Gaussian distributions were verified by the Shapiro-Wilk test, the homogeneity of variance by the Levene test and the sphericity by the Mauchley test. A repeated-measures analysis of variance was used to determine if there was a significant effect of the additional load on the sprinting performance. If significant differences were obtained, a Bonferroni *post-hoc* test was conducted. Also, curve estimation is used to identify the regression equation describing the relationship between load and percentage of velocity lost. Besides, delta-percentage of velocity loss (*Equation 1*: $\Delta_{(\%)} = [(V_1\text{-}V_2)/V_1] \times 100$) was calculated in order to evaluate the variation percentage between the different loads. Significance was set at $p \leq 0.05$. The statistical analyses were performed using the Statistical Package for Social Sciences version 20.0 (SPSS Inc., Chicago, IL, USA)

RESULTS

Sprint performance measures for 15m-run are reported in the Table 2. Sprint time for 15m under the four loaded conditions was significantly different from the unloaded condition ($p<0.05$).

Table 2. **DESCRIPTIVE STATISTICS FOR VARIABLES**

	Variables	Unloaded	7% BM	10% BM	15% BM	20% BM
5m	Sprint performance (s)	1.01±0.03	1.06±0.03*	1.08±0.03*	1.12±0.04*	1.15±0.03*
	Time lost (s)	-----	0.04±0.02	0.06±0.03	0.10±0.03	0.14±0.03
	Maximum velocity ($m.s^{-1}$)	4.93±0.15	4.74±0.13	4.64±0.13	4.49±0.14	4.35±0.12
	Velocity lost (%)	-----	3.90±2.03	5.84±2.39	9.01±2.38	11.71±2.51
10m	Sprint performance (s)	1.71±0.05	1.78±0.04*	1.83±0.04*	1.89±0.05*	1.95±0.05*
	Time lost (s)	-----	0.07±0.03	0.11±0.04	0.18±0.04	0.24±0.06
	Maximum velocity ($m.s^{-1}$)	5.84±0.16	5.61±0.13	5.48±0.13	5.29±0.14	5.13±0.13
	Velocity lost (%)	-----	3.85±1.46	6.09±2.08	9.42±2.04	12.13±2.46
15m	Sprint performance (s)	2.32±0.06	2.42±0.06*	2.48±0.05*	2.56±0.07*	2.64±0.07*
	Time lost (s)	-----	0.09±0.03	0.15±0.04	0.24±0.04	0.31±0.06
	Maximum velocity ($m.s^{-1}$)	6.46±0.16	6.20±0.15	6.06±0.13	5.86±0.16	5.69±0.15
	Velocity lost (%)	-----	3.90±1.26	6.11±1.54	9.24±1.53	11.84±2.12

BM=Body Mass * $p<0.05$ (n=22)

This performance was significantly longer by 4.78% (0.12s), 6.70% (0.17s), 9.45% (0.24s) and 12.11% (0.32s) respectively for 7%, 10%, 15% and 20% BM loaded conditions compared with no load condition. Curve estimation for decreasing of the velocity when the load increased can be represented by the regression equation (Figure 1, Equation 2). The % BM was highly associated with the % Velocity ($p<0.05$) and the R^2 value for this equation was 0.889.

Equation 2: [% BM = (-1.48 × % Velocity) + 148.85]

DISCUSSION

The purpose of this study was to examine the effect of towing loads on velocity achieved during 15m-sprint from starting blocks. The main findings of the present study showed that an increase in towing loads (7%, 10%, 15% and 20% BM) decreases sprint velocity over 15m acceleration (Figure 1). Most of the previous studies used sprinting from a standing start as in team sports, where athletes performed on natural grass surfaces. However, Okkonen and Hakkinen (2013) tried to compare kinetics, kinematics and muscle activity among block-sprint start and sled towing and selected squat-type exercises in track and field athletes on synthetic surface.

In addition, Maulder *et al.* (2008) indicated that sprint velocity became significantly slower with an increase in load compared to the unloaded sprint velocity achieved over 10m without alteration of the start kinematics (loads of approximately 10% and 20% BM). In the current study the athletes performed the velocities with different towing loads (7%, 10%, 15% and 20% BM) over 15m acceleration from starting blocks. Furthermore, the current results allowed posing an equation in order to control the relationship between the towing load and maximum velocity during unloaded sprint [% BM=(-1.48 × % velocity)+148.85].

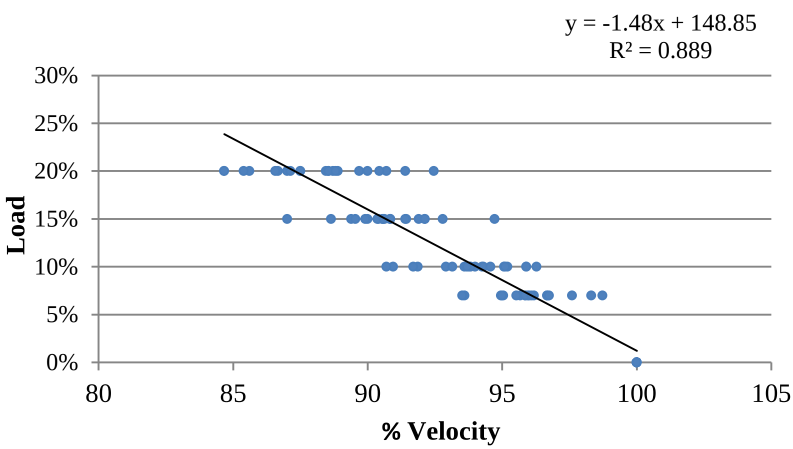

Figure 1. **REGRESSION ANALYSIS OF EFFECT OF INCREASES IN LOAD EXPRESSED IN PERCENTAGE OF BODY MASS ON VELOCITY AS PERCENTAGE OF MAXIMUM SPEED ACHIEVED OVER 15M FROM STARTING BLOCKS**

This regression equation may prove to be a useful tool for coaches in order to program a training session for the sprinters under specific conditions (track spike shoes, tartan synthetic surface and starting blocks). In this context, the proposed equation may allow coaches to identify more accurately the towing load (to 0.1kg) according to the percentage of velocity loss. For example, as presented in Table 3, when programming a training session for 80kg sprinter targeting the 90% of his maximum velocity over a short running distance from starting blocks (0 - 15m) a load of 12.5kg is recommended.

***Table 3*. OPTIMAL LOAD FOR SLED-TOWING IN ACCELERATION TRAINING FROM STARTING BLOCKS**

BM (kg)	% Maximum velocity					
	90%	91%	92%	93%	94%	95%
90	14.1	12.8	11.4	11.0	8.8	7.4
88	13.8	12.5	11.2	10.7	8.6	7.3
86	13.5	10.7	10.9	10.5	8.4	7.1
84	13.1	11.9	10.7	10.3	8.2	6.9
82	12.8	11.6	10.4	10.0	8.0	6.8
80	12.5	11.3	10.2	9.8	7.8	6.6
78	12.2	11.1	9.9	9.5	7.6	6.4
76	10.2	10.8	9.6	9.3	7.4	6.3
74	11.6	10.5	9.4	9.0	7.2	6.1
72	11.3	10.2	9.1	8.8	7.0	5.9
70	11.0	9.9	8.9	8.5	6.8	5.8
68	10.6	9.6	8.6	8.3	6.6	5.6
66	10.3	9.4	8.4	8.1	6.4	5.4
64	10.0	9.1	8.1	7.8	6.2	5.3
62	9.7	8.8	7.9	7.6	6.0	5.1
60	9.4	8.5	7.6	7.3	5.8	5.0

BM=Body Mass

PRACTICAL APPLICATION

The present study attempted to propose a regression equation describing accurately the relationship between the sled-towing loads and the maximum velocity during unloaded 15m-sprint. This may be an addition to the equations presented in previous studies for RST, which were performed on natural grass and synthetic surfaces starting from a standing position.

The equation of the present study allows prediction of the towing load that could be used during the training sessions. It was assumed that the different loads (7% to 20% BM) used with sled-training may be used for progressive muscular adaptations in specific conditions of sprint training, which could enhance performance of the acceleration phase using starting blocks (Bachero-Mena & Gonzalez-Badillo, 2014). Therefore, this method could be recommended to be incorporated in the conditioning programme of sprinters. To better facilitate the application of this equation, the recapitulative table (Table 3) could help coaches and researchers to establish training loads corresponding to different BM and the target speed instantly.

It is important to note that the present formula was established with male sprinters. To be certain of the efficiency of the method, some sled-training sessions are needed before trying with starting blocks, mainly with novices. Furthermore, the way the sled makes contact with the ground and the nature of the running surface will determine the coefficient of friction as mentioned by Alcaraz *et al.* (2009).

These findings provide an important step toward an evidence basis for the use of added loads to sleds as an exercise strategy for male sprinters under specific conditions (track shoes, tartan synthetic surface, starting blocks and weather temperature). Further studies could examine the relationship between the sled-towing load and the velocity for female sprinters and assess the long-term effects of training programmes with a sled on sprint performance and starting technique from starting blocks. In this regard, a longitudinal investigation on the effects of different loads would offer a better understanding of optimal conditions in sprint training.

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