Bulletin of the *Transilvania* University of Braşov
Series IX: Sciences of Human Kinetics • Vol. 15(64) No. 2 – 2022
https://doi.org/10.31926/but.shk.2022.15.64.2.1

EFFECT OF RESISTED SLED SPRINTS IN SPRINT START AND ACCELERATION PERFORMANCE: PRELIMINARY RESULTS

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Abstract: *The purpose of the study was to examine the effect of resisted sled sprints (RSS) on the biomechanical parameters of the first steps of short acceleration sprints. Five track and field athletes performed 10-m sprints using the semi-standing (SSS) and the 3-point (TPS) starting techniques. The RSS condition was conducted with a load of 9.7% ± 0.3 of body mass. Results of the 2 (start technique) × 2 (loading) × 3 (steps) revealed significant ($p < .05$) main effects on average step velocity. Main effects of loading and step were observed for contact time and step length, while a main effect of step was observed in the examined spatiotemporal parameters. No differences ($p > .05$) were evident for flight time and sled pulling force. In conclusion, regardless the starting technique, RSS should be controlled for the avoidance of the excessive loading that was observed at the sprint start.*

Key words: *track and field, technique, training load, step parameters, force.*

1. Introduction

Acceleration is of importance in sprinting, as the transition from a stationary starting position to achieve maximum sprinting velocity as fast as possible is a defining factor for sprinting performance [3], [17], [20]. Thus, power, namely the ability to apply force when moving fast, is essential for the effectiveness of the sprint start and the following acceleration phase [14], [16].

Training methods utilizing external resistance are effective in developing

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acceleration and thus to increase running speed, given the fact that the training design fulfils the requirements of the training principals [11]. For example, the effectiveness of a training program is based on the principal of specificity, i.e., when the gains from strength and power training are translated into sprint-specific movements [8]. The training principle of specificity is also accomplished with a positive transfer of training to athletic performance and, in specific, the case where the training program emphasizes on a similar motor pattern and type of muscle contraction as the competitive movement [9], [19], [26]. A prerequisite for the optimization of resistance training in sprinting is to strictly implement individualized loads based on the practitioner's characteristics [22].

Based on the outcome of literature reviews, resisted sled pulling sprints (RSS) are widely acknowledged as an effective sprint training method [1], [19]. In addition, past [4], [12] and recent [23], [28] research has examined the acute effects of RSS on sprinting kinematics. However, despite the efforts to estimate the resistive forces applied to the athlete+sled system to optimize the loading of the practitioners [5], [15], there is a lack of an accurate estimation method of their magnitude [6]. To the best of our knowledge, there are no corresponding studies in the literature about the sled pulling forces acting on the sprinters during RSS in combination with the effect of the sprint starting technique.

2. Objectives

The aim of the research was to present the preliminary results of the differences in sled pulling forces due to RSS, track start technique and step order in short sprint accelerations in experienced track and field athletes. The sled pulling force recordings were interpreted as indicators of loading. In addition, performance (i.e., time) and the biomechanical parameters of the first four steps after the start of the acceleration sprints were examined to define the effect of RSS. It was hypothesized that RSS will result in different loading profiles between the examined sprint start techniques, as well as that higher value in contact time and performance. In addition, lower values in average speed and step length are expected to be observed due to the RSS.

3. Material and Methods

3.1. Participants

Five adult club level sprinters (24.5 ± 4.5 yrs, 1.80 ± 0.06 m, 70.7 ± 4.5 kg, 15.2 ± 3.8 yrs of training experience; 4 males) were recruited to participate in the study. A record of systematic training, an experience of at least three years in RSS training, the avoidance of intense training on the day prior the measurements, as well as the lack of injury for six months before testing were the inclusion criteria.

All participants signed an informed consent following the recommendations of the Declaration of Helsinki. The study was approved by the Institutional Research Ethics Committee (approval number: 260630/2021).

3.2. Procedure

Testing was conducted in an indoor track facility with rubber surface and an ambient temperature of 22-24°C. The data acquisition sessions were performed in late autumn. All participants were in their preparation period for the indoor competitive season and had been already involved in RSS training for at least two micro cycles.

At first, the participants did their typical warm-up session (10-min running and 10 min dynamic stretching exercises). Then, they wore their custom track suit and spike shoes and executed neuromuscular coordination drills (skipping, scissors and heel-to-butt kicks; 2 x 20 m each exercise), and three 60-m dashes at gradually increasing speed.

Following the warm-up, the 10-m sprint acceleration tests were performed in a randomized order and with maximal intensity. Rest time was at least 3 min to allow recovery. Two attempts in each loading condition, i.e., with (LRS) or without (ULS) pulling the sled, and twice from the semi-standing (SSS) and the 3-point (TPS) starting position, were performed (Figure 1).

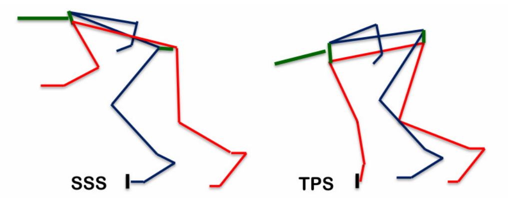

Fig. 1. *Representative stick-figures of the starting techniques (SSS: semi-standing start; TPS: 3-point start)*

For the execution of the SSS, the athletes were instructed to stand at the middle of the lane and to place the front foot right before the start line, with the rear leg placed two feet behind the start line, aiming to the same direction (i.e., pointing perpendicularly to the start line). The upper extremity joints were at right angles, while the opposite arm was aiming forward to the front leg. The torso also leaned forward.

To perform the TPS, the front foot was placed one foot behind the starting line and the rear leg behind the heel of the front leg. The opposite to the front leg hand was placed on the ground right before the starting line, while the other arm was kept at the side of the body, flexed in an approximate 90° angle at the elbow joint. The torso leaned forward and the gaze was fixed on the starting line. For all starts and at the "go" signal, both legs had to push-off explosively.

For the RSS condition, a 6-kg sled was attached to the participants through a stiff rope (length = 2.9 m) and a hip belt. Individualized RSS loading equal to 10% of body mass drop was applied with a 0.25 kg precision range, by using combinations of custom weight plates that were fixed on a vertical fixation column in the middle of the sled. Due to the aforementioned range of precision, the participants were subjected to an average estimated RSS loading of 9.7% ± 0.3 of their body mass, which is considered appropriate for the purpose of the study [1].

3.3. Instrumentation

The body mass was measured using an electronic scale (Delmac PS400L, Delmac Scales PC, Athens, Greece). The body height was measured using a telescopic measuring rod (Seca 220, Seca, Deutschland, Germany).

Performance in the 10-m short sprint acceleration tests (t10m) was measured electronically using two pairs of custom-made photocells. The photocells were attached on fixed tripods at a height of 1.1 m above the surface of the track. The pairs of photocells were placed on either side of the lane and at an interval of 10 m. To avoid the effect of reaction time on t10m, the starting line was set 1.0 m before the first pair of the photocells [21], [27].

The sled pulling forces (F_{SP}) were recorded (sampling frequency: 75 Hz) with a KLink force transducer (Kinvent Biomecanique, Montpellier, France) attached to the sled and being in series with the rope. Data acquisition was accomplished in a wireless mode using the KForce App Pro+ application (Kinvent Biomecanique, Montpellier, France) via an Apple iPhone.

The kinematic parameters of the four first steps of the 10-m short acceleration sprint tests were recorded using a stationary Casio Exilim-Pro-EX-F1 (Casio Computer Co. Ltd., Shibuya, Japan) digital video camera. Its optical axis was perpendicular to the plane of motion. The camera was fixed on a tripod at a height of 1.5 m and operated at a sampling frequency of 300 fps. The tripod was positioned approximately 8 m from the inside line of the lane. To conduct the 2D-DLT kinematic analysis [10], two 2.5 m × 0.02 m calibration poles with 12 control markers were placed vertically throughout the filming view.

3.4. Data analysis

The F_{SP} time series were analyzed using the KForce App Pro+ application (Kinvent Biomecanique, Montpellier, France) and Matlab R2021 scripts (The MathWorks Inc., Natick, MA). The peak F_{SP} and the average F_{SP} were extracted and expressed relative to the sled's mass.

The kinematical parameters were extracted using the APAS WIZARD 14.1.0.5 (Ariel Dynamics Inc., Trabuco Canyon, CA, USA) and the Kinovea 0.9.4 (©: Joan Charmant and the Kinovea Community) softwares. The extracted parameters were the step length (SL), frequency (SV), and average velocity (SV), as well as the contact (t_C) and flight (t_{FL}) time. Finally, the maximum knee flexion angle (θ_{MKF}) was recorded for each step (Figure 2). Due to a random incident during the recording of some trials, the first step of the acceleration sprints was excluded from the analysis.

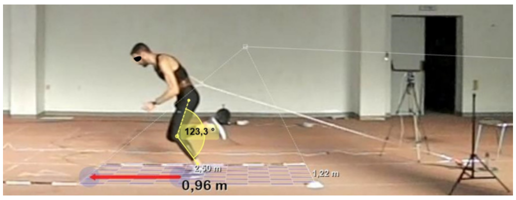

Fig. 2. *Experimental set up and graphical depiction of the data analyses procedures*

3.5. Statistical analysis

In total, 40 trials were recorded and analyzed. Equality of variance and normality of distribution were assessed using the Levene's and the Kolmogorov-Smirnov's tests, respectively ($p > .05$). A 2 (starting technique) × 2 (loading) × 3 (step) repeated measures ANOVA with Bonferroni adjustment was used to establish the main effects and the interaction of the examined factors on the measured parameters of the 10-m acceleration sprint. Pairwise comparisons were run in the case where significant differences were observed. The partial eta-squared statistic (η_p^2) was used to evaluate the effect size ($\eta_p^2 > 0.01$: small; $\eta_p^2 > 0.06$: medium; $\eta_p^2 > 0.14$: large) [24].

A 2 (starting technique) × 2 (loading) repeated measures ANOVA was conducted to check possible differences in t10m. Furthermore, an independent samples *T*-test was run to examine possible F_{SP} differences between TPS and SSS. Cohen's *d* was computed to interpret the effect size ($d < 0.5$: small; $0.5 \le d < 0.8$: medium; $d \ge 0.8$: large). [24].

All statistical tests were run using the IBM SPSS Statistics v.27 software (International Business Machines Corp., Armonk, NY, USA). The significance level was set to a = .05.

4. Results and Discussions

4.1. Performance parameters

RSS resulted in a significant loading (F = 21,575, p < .001, η_p^2 = .375; large effect size) main effect in performance, as t10m decreased by 7.9% in TPS and 5.6% in SSS (TPS: 1.78 ± 0.06 s vs. 1.92 ± 0.09 s and SSS: 1.79 ± 0.08 s vs. 1.89 ± 0.07 s; ULS vs. LRS, respectively). No main effect of the starting technique was observed (F = 0,137, p = .714, η_p^2 = .004; small effect size).

As expected, RSS increased sprint time [4], [25]. However, the absence of a starting technique effect is not in agreement with past findings [7]. This can be attributed to the fact that experienced sprinters instead of team sport players were examined in this study.

4.2. Pulling force parameters

The results of the T-test revealed no significant differences in peak F_{SP} (TPS = 2.30 ± 0.60 N/kg; SSS = 2.19 ± 0.40 N/kg; t = ,644, p = .536; d = .56; medium effect size). However, it is worth noting that: a) peak F_{SP} was over two-times larger than the determined individualized loading of the RSS at the initiation for the first step, and b) average F_{SP} progressively decreased and was approximately 60% of the expected individualized RSS loading (Figure 3).

The use of RSS increases the athlete+sled system inertia. Thus, increased force is required to accelerate, added the fact that, due to the sled's mass and friction, the resistive forces are also increased, resulting eventually in reduced acceleration [6]. Nevertheless, this study fills the gap in the literature as no direct sled pulling forces have been reported in the past for the entire sprint. The present findings suggest that proper attention should be given when designing RSS training programs, because the effort of the sprinter to gain accelerate results in a large, instant loading that excesses by far the desired loading meant to be imposed with the sled resistance, as also observed in the past [13].

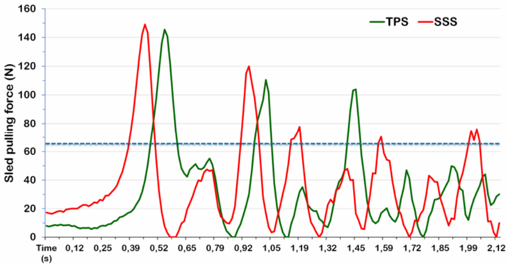

Fig. 3. *Representative sled pulling force-time curves (TPS: 3-point start; SSS: semi-standing start). The horizontal dashed line indicates the mass of the sled*

4.3. Step parameters

Figure 4 depicts the results for the step parameters. There was a significant load (F = 4.912, p = .029, η_p^2 = .044; small effect size) and step (F = 13.486, p < .001, η_p^2 = .201; large effect size) main effect in t_C. No significant start technique main effect was observed (F = .193, p = .661, η_p^2 = .002). On the opposite, there was no significant (p > .05) main effect of start technique (F =.002, p = .963, η_p^2 = .000), loading (F =.755, p = .387, η_p^2 = .007), and step (F = 1.744, p = .180, η_p^2 = .032) on t_{FL}. The increase of t_C was expected [4], [12], [23], [25], since the added load in RSS increases the demand for force output during the stance phase. No differences were found for t_{FL}, unlike past findings [4], [25]. However, research has provided evidence that t_{FL} was not changed after an RSS intervention [28].

Concerning SF, a significant step main effect was revealed ($F = 5.099$, $p = .008$, $\eta_p^2 = .088$; medium effect size), but not significant main effects of start technique and loading ($F = .223$, $p = .638$, $\eta_p^2 = .002$, and $F = 1.372$, $p = .244$, $\eta_p^2 = .013$, respectively). This does not confirm past findings [4]. However, there is bias in the literature, since SF was not subjected to changes after RSS training [28] and loading [25]. The lack of changes in the present study might be attributed to the implementation of a light load (≈10%) to the participants, as this load is believed to be a light overload that cannot alter the movement pattern and velocity [1].

Significant load ($F = 12.928$, $p < .001$, $\eta_p^2 = .111$; medium effect size) and step main effects ($F = 36.581$, $p < .001$, $\eta_p^2 = .413$; large effect size), but not a significant start technique main effect ($F = 3.295$, $p = .072$, $\eta_p^2 = .031$) were evident for SL. In general, RSS results in decreased SL [4], [25] due to the larger external load that deprives sprinters to effectively apply their power capability to perform with the same SL in ULS. In general, the SL of the first steps is characterized by large homogeneity [20]. Thus, it seems that the examined sprinters had an individualized speed development pattern that favored SF over SL. This pattern is not uncommon in the literature and it is proposed to exist as an option to gain speed in the acceleration phase [3].

Finally, there was a significant start technique ($F = 6.943$, $p = .010$, $\eta_p^2 = .063$; medium effect size), load ($F = 28.090$, $p < .001$, $\eta_p^2 = .213$; large effect size), and step ($F = 78.369$, $p < .001$, $\eta_p^2 = .601$; large effect size) main effect in SV. Significant ($p < .001$) pairwise differences were observed from the 3rd step onwards for all factors, confirming past suggestions that the 3rd step after the start is essential for performance in acceleration sprints [18], [25], [27].

4.4. Knee joint angle

No within step differences were observed for θ_{MKF} due to loading ($F = 0.883$, $p = .350$, $\eta_p^2 = .008$) and start technique ($F = 2.792$, $p = .098$, $\eta_p^2 = .025$; small effect size). On the opposite, there was a significant step order main effect (Figure 4f). θ_{MKF} decreased as the participants receded from the start line ($F = 17.716$, $p < .001$, $\eta_p^2 = .247$; large effect size). This finding confirms previous results [4]. The less flexed knee joint during the progression of the sprint indicates the optimization of leg stiffness which is an important factor for developing maximum sprint velocity [2]. In addition, the step main effect was evident in previous research that found less extended knee joint angles in RSS trials compared to ULS only at the touchdown of the first two steps and not at the following steps [23]. On the other hand, the absence of within step differences due to the loading can also be attributed to the light load imposed to the participants.

In summary, the generalization of the present findings should consider the limitations of the study, since a small number of participants were examined. In addition, the RSS was set to a single rather than a range of individualized loading. Future research should examine the sled pulling force-time curves over a wider range of resistance and in a variety of sprinting distances, along with the effectiveness of RSS when starting from starting blocks.

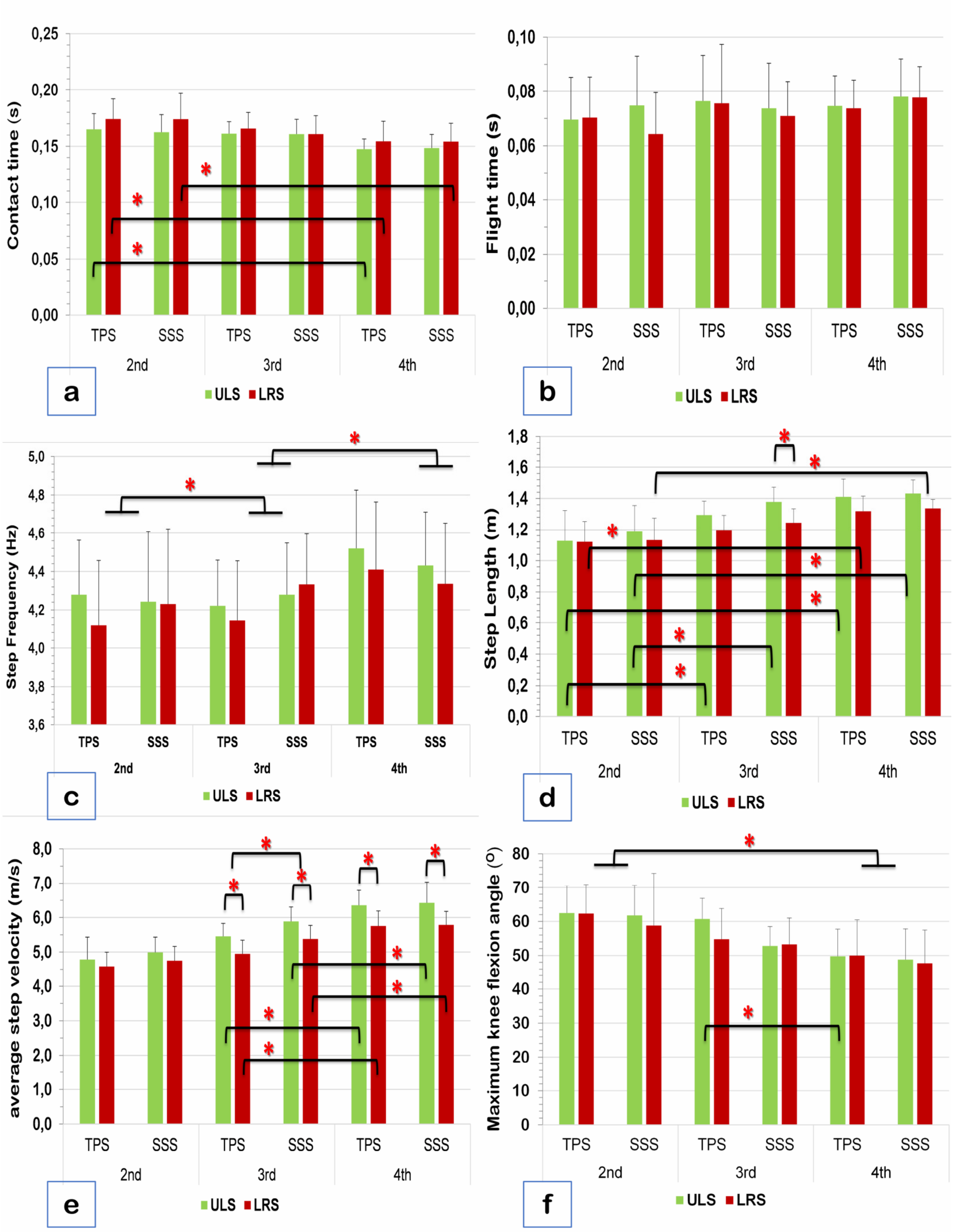

Fig. 4. *Results of the examined biomechanical parameters for the 2nd, 3rd, and 4th step of the 10-m short acceleration sprint tests (TPS: 3-point start; SSS: semi-standing start; ULS: unloaded sprints; LRS: sled load resisted sprints; *: p < .05)*

5. Conclusions

The purpose of this study was to investigate the possible differences due to sled pulling resistance and starting techniques in the performance of club level sprinters when executing a short acceleration sprint. Results revealed a significant loading but not a starting technique main effect. This was mainly due to the higher demands for power production due to the implemented load, but the external resistance seemed not to comprise an overload provoking changes in the sprinting pattern.

Based on the findings of the study, since large fluctuations of the sled pulling force were recorded during the short acceleration sprint tests, RSS should be controlled because of the excessive resistance occurring at the sprint start to avoid excessive loading and, thus, possible injuries.

Acknowledgements

The research was part of the #73355 Research Project of the Research Committee of the Aristotle University of Thessaloniki, Greece, that was funded by Kinvent Biomecanique (Montpellier, France). The authors declare no conflict of interest since the funder did not have a role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, and in the decision to publish the results.

The manuscript is based on the first author’s Graduate Thesis. Parts of the project were presented at the 11th International Congress “Sports Medicine in the 21st Century” and the 24th International e-Congress of the Northern Greece Physical Education Teachers Association.

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