

Effects of Moderate-to-Heavy Sled Training Using Different Magnitudes of Velocity Loss in Professional Soccer Players

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Abstract

Grazioli, R, Loturco, I, Lopez, P, Setuain, I, Goulart, J, Veeck, F, Inácio, M, Izquierdo, M, Pinto, RS, and Cadore, EL. Effects of moderate-to-heavy sled training using different magnitudes of velocity loss in professional soccer players. *J Strength Cond Res* XX(X): 000–000, 2020—This study investigated the effects of a 11-week moderate-to-heavy sled training intervention with different magnitudes of velocity loss on sprint and jump performance, mechanical muscle function, and body composition in professional soccer players. Seventeen players (age 25.8 ± 4.3 years; height 180.0 ± 8.6 cm; weight 77.7 ± 9.7 kg) were randomly allocated into 2 groups, based on different magnitudes of velocity loss: 10% of velocity decrease (G10, $n = 8$) and 20% of velocity decrease (G20, $n = 9$). The velocity-based sled training consisted of 20-m resisted sprints with a progressive loading increase from 45 to 65% of body-mass throughout the intervention. Pre-intervention and postintervention sprint and jump performance, hamstring and quadriceps peak torque and isometric rate of torque development, and lower-limb lean mass measured by dual X-ray absorptiometry were assessed and compared. Two-way repeated measures analysis of variance revealed a significant time-effect for decreases in 10- and 20-m sprint times ($p = 0.018$ and $p = 0.033$, respectively), but without a time-group interaction. The G10 showed greater beneficial effects than G20 for both 10-m ($-5.5 \pm 3.3\%$, magnitude-based inference [MBI]: possibly vs. $-1.7 \pm 5.9\%$, MBI: possibly trivial) and 20-m ($-2.5 \pm 2.1\%$, MBI: possibly vs. $-1.4 \pm 3.7\%$, MBI: likely trivial) sprint times. Moreover, there was a significant time effect for countermovement jump height and quadriceps isometric peak torque, which decreased significantly after training ($p = 0.019$ and $p = 0.010$, respectively), with no within-group effect of time vs. group interaction for these respective outcomes. The novel velocity-based sled model proposed here, especially under lower magnitudes of velocity loss, was able to significantly improve linear sprint performance in professional soccer players.

Key Words: sports performance, sprint training, velocity-based linear acceleration, football

Introduction

The number of high-velocity actions in professional soccer has progressively increased during the past several years (3). These moments are crucial for more than half of goals scored during modern tournaments, and elite players are required to be faster over successive seasons (18). Another important issue is that one of the most prevalent injuries in this team-sport (i.e., hamstring strain) (13) is susceptible to occur during maximum sprint efforts (9,28). Thus, the capacity of athletes to perform well and cope with these strenuous (and frequent) motor tasks during matches is paramount. Under this rationale, training strategies aiming to improve speed-related performance may have relevant benefits and implications for professional soccer players.

Among these strategies, the sled towing exercise has been commonly used by coaches and sport scientists in practical and research settings (31). Nevertheless, there are important controversies regarding sled-load magnitude, since several studies

recommend a limit of ~20% of body-mass (BM) (1), whereas few recent investigations have suggested the use of much heavier loads (i.e., $\geq 60\%$ BM) (10,26). This discussion has major implications in the sled training prescription, once there are divergent bodies of work suggesting opposed load instructions (1,2,10,11,27,30). Along with the paucity of data regarding the effects of either moderate (i.e., 45% BM) or heavy sled sprint training (i.e., $\geq 60\%$ BM) in elite team-sport athletes, this contradictory scenario reinforces the need for longitudinal research on this topic.

In traditional strength or power training (e.g., squats, jump squats, and plyometric exercises), the velocity-based approach is commonly used to optimize performance gains (15,23,29). Accordingly, it seems that higher magnitudes of velocity loss during sets may be counterproductive (i.e., lower power output increases and the percentage of myosin heavy chain IIX is reduced longitudinally) (29). As a consequence, the use of these velocity-based training models has been encouraged to improve and monitor athletes' performance. Concerning sled towing, the velocity-based concept has been recently matured and it is usually prescribed from the decreases imposed by a given load on unloaded sprint velocity, using relative rates of velocity loss

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(8,30). However, in this training strategy, the number of repetitions is fixed, differently from the original velocity-based training model, which considers the magnitude of fatigue across repetitions, limiting the sets based on pre-established thresholds of velocity loss (29). This is a factor for resisted sprints, because different subjects, with distinct neuromuscular and physiological profiles, will probably experience (and respond to) different training loads. Thus, it is important to develop a novel method to prescribe resisted sled pulling, for example, using a training scheme that allows practitioners to better and more accurately individualize the workloads. Nonetheless, to date, no study has investigated the effects of “velocity-based sled training” on the functional performance of professional soccer players.

This study aimed to compare the effects of 11 weeks of moderate-to-heavy sled training (i.e., 45–65% BM) with different magnitudes of velocity loss (i.e., 10 vs. 20%) on sprint (i.e., 10 and 20 m) and jump performance (i.e., countermovement [CMJs] and squat jumps [SJ]), mechanical muscle function (assessed by isokinetic testing), and lower-limb lean mass (evaluated by dual-energy X-ray absorptiometry [DXA]) in professional soccer players. Based on previous findings regarding different velocity-based training interventions (15,29), it was hypothesized that lower magnitudes of velocity loss (i.e., 10%) would elicit superior performance gains.

Methods

Experimental Approach to the Problem

This is a 2-arm quasi-experimental study (i.e., no control group) investigating the effects of 2 different moderate-to-heavy sled training approaches (independent variables) on 10- and 20-m sprint performance (primary dependent variables), and jump performance, isokinetic measures, and lower-limb lean mass (secondary dependent variables). Furthermore, players' field positions and the traditional soccer training loads could be considered possible confounders variables in our experimental design. To compare the effects of different magnitudes of velocity loss during longitudinal moderate-to-heavy sled training, the subjects were divided into 2 different velocity-based percentage groups (i.e., 10 and 20%). The players performed 11 weeks of moderate-to-heavy sled training (i.e., once a week) along with traditional soccer training. They completed 10 sled training sessions and 10 matches (i.e., 7 officials and 3 nonofficials) throughout this period.

Subjects

The initial sample comprised of 22 male professional soccer players from a Brazilian club participating in the first division state and National cup. Informed consent was obtained from all subjects before testing. Subjects were asymptomatic and free of injuries, participating in training sessions on average 6 times per week, and not using any type of stimulants that could affect their performance. The study was approved by the Federal University of Rio Grande do Sul ethics committee and performed in accordance with the Helsinki Declaration for ethical principles in medical research involving human subjects. Five athletes were excluded from the analyses: 3 were transferred to other clubs and 2 experienced contact knee injuries. Thus, 17 professional soccer players (age 25.8 ± 4.3 years; height 180.0 ± 8.6 cm; weight 77.7 ± 9.7 kg) completed the study. The athletes were randomly assigned to 2 groups with different velocity loss magnitudes: 1

with 10% of velocity loss allowed during repetitions (G10, $n = 8$, 1 defender, 1 left side, 3 midfielders, and 3 attackers), and the other with 20% of velocity loss (G20, $n = 9$, 2 defenders, 1 left side, 1 right side, 3 midfielders, and 2 attackers). The randomization was conducted after the baseline assessment and the allocation concealment was done by an independent researcher, blinded to the details of the study. Using the study by Kawamori et al. (21) as reference, to achieve an 80% power with α of 0.05 (2-tailed), 7 subjects per group were required to detect an average change of 0.11 seconds in the 10-m sprint time (SD of 0.08 seconds, effect size [ES] of -1.57).

Procedures

The assessments were always executed in the following order: (a) DXA, (b) jump and sprint performance, and (c) isokinetic testing; starting from body composition (to avoid accentuated fluid changes during performance procedures) (4) and subsequently the jump and sprint performance and isokinetic measurements. Once included, the athlete attended 2 sessions in laboratory: (a) pretraining and (b) post-training evaluations. Each pre-intervention and post-intervention test was supervised by the same investigator, who was blinded to the experimental training group. During the physical testing and training sessions, the players were encouraged by 2 researchers and their technical staff to perform the trials as fast and as hard as possible. The athletes were previously familiarized with testing (i.e., periodic evaluation in the facilities) and training procedures (i.e., a familiarization session of 4 sprint bouts with 45% BM without velocity control).

Training Program. Subjects performed 11 weeks of moderate-to-heavy sled sprint training (4 preseason and 7 in-season) composed by 20-m straight-line sprint trials using a weighted sled (Fitness Beat, São Paulo, Brazil). A 2.5-m cord connected the sled to the players by means of a waist harness. The intensity was progressively prescribed according to individual BM. Along with the sled-mass (i.e., 6 kg), the load started from 45% of BM in the first session, increasing 5% in each training session until the fifth week, in which 65% BM was reached and maintained until the end of intervention. Velocity loss thresholds (10 vs. 20%) across repetitions were monitored using a radar gun (Bushnell 101911; 02-13, Kansas), positioned and directed posteriorly to the subjects' center of mass. Before each session, athletes performed 10 minutes of a specific warm-up including moderate running, dynamic stretching, skipping exercises, and preparatory sprint drills. During the workouts, the G10 and G20 performed repetitions until the velocity decreased to 10 and 20%, respectively, compared with the maximum velocity achieved with sled in the first 2–4 repetitions of each session. The magnitudes of velocity loss were controlled using an Excel spreadsheet. Although 1 researcher assessed the velocity using the radar gun, a second researcher immediately added the values to the spreadsheet and identified the respective decrements in velocity across repetitions. When the athlete reached twice the correspondent percentage of reduction (i.e., ≥ 10 or 20%), according to the group, the training was immediately interrupted. The rest between each repetition was fixed at 30 seconds, given the necessary time to approach the training sessions for the next players. The sled training was always performed on the same outdoor lawn (synthetic) and the athletes used soccer cleats and the same uniform. In case of raining events, the sessions were conducted on an indoor space with a similar synthetic grass (12). Besides sled intervention, the

professional athletes had to be involved in the same traditional soccer training routine (379.1 ± 26.1 minutes of training per week), consisting of small-sided games, nonperiodized core stability and strengthening exercises, offensive and defensive transitions, and tactical aspects (i.e., positional situations, dead balls, ball circulation). Three researchers (R.G., M.L., F.V.) accompanied the workouts to ensure that no additional effort would be done. Thus, only the resisted sprint training programs were different between groups.

Sprint Performance. Three photocells (Speed-Test; Cefise, São Paulo, Brazil) were positioned at the starting line and at the distances of 10 and 20 m. The soccer players sprinted 3 times, starting from a standing position, 1 m behind the starting line. The pretest and post-test were conducted on the same outdoor soccer field where the team usually trained, with players using the same soccer cleats. A 3-minute rest interval was allowed between the attempts. The fastest time was considered for analyses.

Jump Performance. Subjects performed the SJ and CMJ attempts on a contact mat (Jump-System Pro; Cefise), with the hands fixed on the hips. Jump height was determined using an acknowledged flight-time calculation (6). A variation of 3% was established as the minimum between valid attempts. During the SJ, subjects were required to initiate the movement with their knees close to 90° and avoid any countermovement; during the CMJ, they initiated the movement from a standing position. They were given 3 trials to obtain their maximum jump height in each test, with 10 seconds of rest between them. The highest value was recorded for analysis (7).

Isokinetic Evaluation. Maximal isometric and isokinetic hamstring and quadriceps peak torque (PT) and isometric rate of torque development (RTD) were assessed using an isokinetic dynamometer (Cybex Norm, Ronkonkoma, NY). Subjects were seated with their hips and thighs firmly strapped to the seat of the dynamometer, with the hip angle at 85°. After that, the subjects warmed up performing 12 submaximal knee extension and flexion repetitions at $120^\circ \cdot s^{-1}$ using the dominant leg. Subjects were then instructed to perform 5 maximal concentric knee extension and flexion repetitions at $60^\circ \cdot s^{-1}$ through a 90° range of motion (i.e., 0° full extension). After that, they performed 5 maximal eccentric knee flexion repetitions at $60^\circ \cdot s^{-1}$. Thereafter, the subjects were instructed to isometrically produce the maximal knee extension and flexion force as fast as possible for 3 seconds (each attempt) at 30° (16,26,32). The rest interval between the consecutive attempts was fixed at 2 minutes. The torque-time curve was obtained using Miotoool software sampled at 600 Hz. Maximal PT was defined as the highest torque value determined with the dynamometer's HUMAC2009 software (with gravity corrections). The RTD was derived from the average slope of the moment-time curve ($N \cdot m \cdot s^{-1}$) over time intervals of 0–350 milliseconds relative to the onset of contraction, which was considered the point at which the torque exceeded 7.5 N·m and determined using the MATLAB software routine. The isometric force-time analysis on the absolute scale included the maximal RTD, defined as the greatest torque value obtained in 0–350 milliseconds using Excel software. In addition to the maximal RTD, the RTDs at 0–50-millisecond (early) and 100–200-millisecond (late) intervals were calculated.

Body Composition. Lower-limb lean mass was evaluated by DXA–Lunar (Model DPX-L; Lunar Radiation Corp., Madison,

WI), which was calibrated before testing. Each player was asked to lie down in the supine position without moving during the measurements for approximately 5 minutes, while the arm of the equipment scanned their body, from head to foot. The lower-limb free fat mass was automatically calculated using the proprietary software.

Statistical Analyses

Data are presented as the mean \pm SD. The Shapiro-Wilk and Levene tests were used for normality and homogeneity, respectively. Training and subjects characteristics were compared using an independent *t*-test. A repeated measures analysis of variance (ANOVA) (group \times time) was used to analyze the effects of training on the study outcomes. Data were analyzed using SPSS statistical software package (version 22; SPSS, Inc., Chicago, IL) and the level of significance was set at $\alpha = 0.05$. Effect sizes were calculated by the difference between pretest and post-test scores, divided by the pooled SD and ES were interpreted as: $ES \leq 0.2$, trivial effect; 0.2–0.5, small effect; 0.5–0.8, moderate effect; and $ES > 0.8$, large effect. In addition, the magnitude-based inferences (MBIs) were calculated (5). The magnitude of the within-group changes in the distinct variables, or between-group differences in the changes, were expressed as standardized mean differences. The smallest worthwhile change was set using a small ES ($ES = 0.2$) for each variable tested (19). The quantitative chances of finding differences in the variables were assessed qualitatively as follows: $<1\%$, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; and $>99\%$, almost certain. A meaningful difference was considered using the clinical inference, based on threshold chances of “harm” and “benefit” of 0.5 and 25% (18). Moreover, the magnitudes of the standardized differences were interpreted using the following thresholds: <0.2 , 0.2–0.6, 0.6–1.2, 1.2–2.0, 2.0–4.0, and >4.0 for trivial, small, moderate, large, very large, and near perfect, respectively (19).

Results

Data showed normality and homogeneity of variance. The subjects and training characteristics are described in Table 1. The G10 performed 31% less repetitions and total sprint distance than G20 ($p < 0.05$) (Table 1). The repeated measures ANOVA revealed a time-effect for decreases in 10-m (Figure 1) and 20-m sprint times (Figure 2) ($p = 0.018$ and $p = 0.033$, respectively), without time-group interaction ($p > 0.05$). The G10 showed greater beneficial effects than G20 on 10-m ($-5.5 \pm 3.3\%$; MBI: possibly vs. $-1.7 \pm 5.9\%$, MBI: possibly trivial) and 20-m ($-2.5 \pm 2.1\%$, MBI: possibly vs. $-1.4 \pm 3.7\%$, MBI: likely trivial) sprint times.

Table 1
Subjects and training characteristics.

	10% group (G10, $n = 8$)	20% group (G20, $n = 9$)
Age (y)	26.25 \pm 5.31	25.44 \pm 3.57
Weight (kg)	75.76 \pm 9.76	79.45 \pm 9.94
Height (cm)	178.62 \pm 9.48	181.22 \pm 8.19
Played minutes (min)	544.12 \pm 355.47	572 \pm 284.98
Velocity loss (%)	14.73 \pm 2.67*	26.46 \pm 4.00*
Repetitions	33.75 \pm 9.22*	48.78 \pm 7.50*
Total distance (m)	675.00 \pm 184.47*	975.56 \pm 149.93*

*Independent *t*-test revealed differences between groups for total distance ($p = 0.002$), repetitions ($p = 0.002$), and velocity loss ($p = 0.0002$), whereas played minutes were not different ($p = 0.86$).

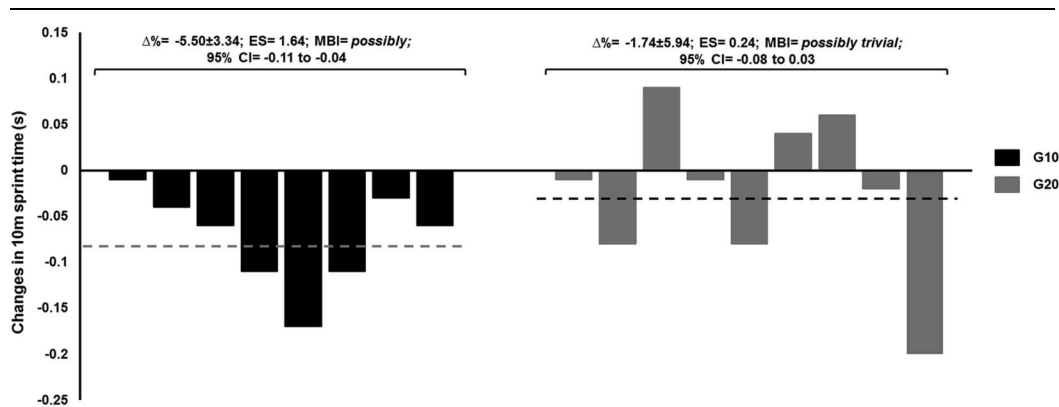


Figure 1. Individual changes of 10-m sprint times in 10% group (G10, black columns) and 20% group (G20, gray columns). Dashed lines = means; ES = effect size; MBI = magnitude-based inferences; 95% CI = confidence interval at 95% of mean differences; Δ% = relative changes.

In contrast, there was a significant time effect for decreases in CMJ ($p = 0.019$; G10 = $-1.7 \pm 6.7\%$, MBI: likely trivial; G20 = $-7.1 \pm 4.7\%$, MBI: very likely trivial) and quadriceps isometric PT ($p = 0.010$; G10 = $-4.7 \pm 12.8\%$, MBI: likely trivial; G20 = $-14.4 \pm 12.5\%$, MBI: very likely trivial), without time-group interaction in these respective outcomes ($p > 0.05$). No additional significant time and group effect, or time vs. group interaction was observed ($p > 0.05$). Pretraining and post-training values, pre-post test correlation coefficient, mean differences with confidence interval at 95%, relative changes, ES with confidence interval at 95%, and MBI of sprint performance, jump performance, and RTD are demonstrated in Table 2. Furthermore, these same information for lower-limb lean mass and hamstring and quadriceps maximal strength are exposed in Table 3. The SEM of 10- and 20-m sprint times were 0.04 and 0.07 seconds, respectively, and 0.42 cm for CMJ height.

Discussion

The main finding of this study was that G10, who performed 31% less repetitions than G20 as a consequence of the velocity-based approach, exhibited greater beneficial effects on sprint performance after 11 weeks of resisted sprint training, in addition to their regular soccer training routine. Moreover, some mechanical

muscle function outcomes showed significant impairments, which were more pronounced in G20. Therefore, the current model of velocity-based sled towing using moderate-to-heavy loading conditions seems to be effective at increasing sprint ability in professional soccer players during the preseason and in-season period, especially when lower rates of velocity decrements are applied. This is the first study to assess and compare the effects of different magnitudes of velocity decreases during moderate-to-heavy sled sprint training in elite team-sport athletes.

To our knowledge, only 2 experimental studies have investigated the chronic effects of implementing heavy and very-heavy sled training strategies. Kawamori and co-workers (21) compared the effects of 2 different overloads (termed as heavy- or light-load by the authors) on sprint ability in 21 physically active men throughout an 8-week training program. The authors used a typical velocity-based approach in which the “heavy” (i.e., ~45% BM) and “light” (i.e., ~12% BM) groups performed weighted sled towing which decreased unloaded 10-m sprint velocity by approximately 30% (heavy group) and 10% (light group). The heavy-load group significantly improved both 5- and 10-m sprint times by 5.7 and 5.0%, respectively, whereas only 10-m sprint time was significantly improved by 3.0% in the light-load group. These findings agree with our data, given that, similar to our findings, a moderate-to-heavy range of load (i.e., 45–65% BM) was able to improve 5- and 10-m sprint performance in

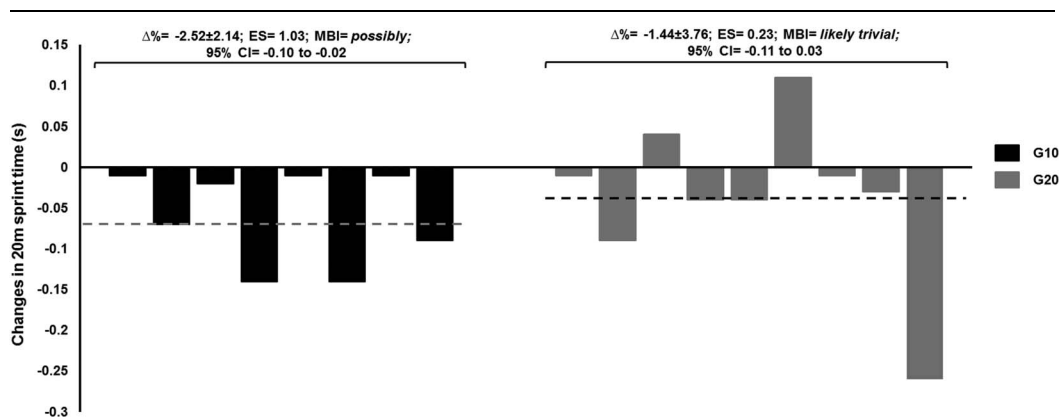


Figure 2. Individual changes of 20 m sprint times in 10% group (G10, black columns) and 20% group (G20, gray columns). Dashed lines = means; ES = effect size; MBI = magnitude-based inferences; 95% CI = confidence interval at 95% of mean differences; Δ% = relative changes.

Table 2**Sprint performance, jump performance, and rate of torque development data before and after training.***

	Groups	Pre	Post	<i>r</i>	Δ (95% CI)	Δ%	ES (95% CI)	% Chance rating
10-m sprint time (s)	G10	1.60 ± 0.05	1.52 ± 0.06	0.56	-0.07 ± 0.05† (-0.11 to -0.04)	-5.50 ± 3.34	-1.64 (-2.32 to -0.96)	71/28/0 <i>possibly</i>
	G20	1.57 ± 0.11	1.55 ± 0.09	0.56	-0.02 ± 0.09† (-0.08 to 0.03)	-1.74 ± 5.94	-0.24 (-0.82 to 0.34)	43/56/0 <i>possibly trivial</i>
20-m sprint time (s)	G10	2.83 ± 0.07	2.76 ± 0.08	0.73	-0.06 ± 0.06† (-0.10 to -0.02)	-2.52 ± 2.14	-1.03 (-1.64 to -0.43)	36/63/0 <i>possibly</i>
	G20	2.79 ± 0.17	2.75 ± 0.12	0.79	-0.04 ± 0.10† (-0.11 to 0.03)	-1.44 ± 3.76	-0.23 (-0.63 to 0.17)	10/89/0 <i>likely trivial</i>
CMJ (cm)	G10	39.34 ± 4.91	38.71 ± 4.41	1.00	-0.63 ± 2.70† (-2.50 to 1.24)	-1.70 ± 6.68	-0.12 (-0.51 to 0.25)	0/88/10 <i>likely trivial</i>
	G20	41.34 ± 4.77	38.62 ± 4.27	0.93	-2.71 ± 1.82† (-3.90 to -1.53)	-7.08 ± 4.69	-0.57 (-0.82 to -0.32)	0/99/0 <i>very likely trivial</i>
SJ (cm)	G10	34.97 ± 3.73	35.77 ± 3.64	0.69	0.80 ± 2.89 (-1.20 to 2.80)	1.99 ± 7.77	0.21 (-0.32 to 0.75)	0/79/20 <i>likely trivial</i>
	G20	38.40 ± 4.81	34.78 ± 2.40	0.76	-2.58 ± 2.96 (-4.52 to -0.65)	-7.31 ± 8.29	-0.75 (-0.94 to -0.13)	3/96/0 <i>very likely trivial</i>
Quadriceps MRTD (N·m·s ⁻¹)	G10	1,388.19 ± 678.77	1,212.61 ± 398.14	0.84	-174.58 ± 404.23 (-454.69 to 105.53)	-14.06 ± 33.88	-0.26 (-0.67 to 0.16)	12/79/8 <i>likely trivial</i>
	G20	1,872.74 ± 598.00	1,765.11 ± 434.20	0.21	-165.05 ± 672.19 (-604.21 to 274.11)	-17.73 ± 58.71	-0.18 (-1.01 to 0.46)	3/96/0 <i>very likely trivial</i>
Quadriceps RTD _{0-50 ms} (N·m·s ⁻¹)	G10	579.82 ± 391.26	509.66 ± 234.62	0.84	-70.17 ± 233.43 (-231.92 to 91.59)	-13.71 ± 39.11	-0.18 (-0.59 to 0.23)	8/86/4 <i>likely trivial</i>
	G20	837.71 ± 316.46	811.59 ± 252.93	0.46	-68.97 ± 296.55 (-262.72 to 124.77)	-19.70 ± 62.25	-0.08 (-0.83 to 0.39)	0/99/0 <i>very likely trivial</i>
Quadriceps RTD _{100-200 ms} (N·m·s ⁻¹)	G10	1,419.19 ± 450.49	1,301.21 ± 341.23	0.79	-117.98 ± 273.93 (-307.80 to 71.84)	-9.87 ± 22.08	-0.26 (-0.68 to 0.16)	11/77/10 <i>likely trivial</i>
	G20	1,806.73 ± 476.84	1,672.62 ± 356.65	0.42	-152.91 ± 480.72 (-466.97 to 161.16)	-12.83 ± 40.35	-0.28 (-0.98 to 0.34)	3/95/0 <i>very likely trivial</i>
Hamstring MRTD (N·m·s ⁻¹)	G10	975.54 ± 182.23	918.70 ± 142.58	0.26	-56.85 ± 259.02 (-236.34 to 122.64)	-9.16 ± 31.19	-0.31 (-1.30 to 0.67)	12/64/23 <i>possibly trivial</i>
	G20	1,409.68 ± 534.85	1,118.50 ± 429.76	0.36	-314.10 ± 599.09 (-705.50 to 77.30)	-39.12 ± 65.33	-0.54 (-1.32 to 0.14)	14/85/0 <i>likely trivial</i>
Hamstring RTD _{0-50 ms} (N·m·s ⁻¹)	G10	311.91 ± 91.78	293.13 ± 63.57	0.37	-18.78 ± 90.18 (-81.28 to 43.71)	-8.12 ± 26.64	-0.20 (-0.89 to 0.48)	15/75/9 <i>likely trivial</i>
	G20	530.24 ± 296.47	508.21 ± 230.75	0.27	-54.47 ± 331.26 (-270.89 to 161.95)	-21.02 ± 70.23	-0.07 (-0.91 to 0.55)	2/96/0 <i>very likely trivial</i>
Hamstring RTD _{100-200 ms} (N·m·s ⁻¹)	G10	1,005.03 ± 141.03	970.91 ± 102.20	0.00	-34.12 ± 174.43 (-154.99 to 86.75)	-4.53 ± 18.38	-0.24 (-1.10 to 0.62)	14/69/16 <i>possibly trivial</i>
	G20	1,304.48 ± 339.53	1,176.27 ± 362.64	0.82	-179.75 ± 224.00 (-326.10 to -33.41)	-18.06 ± 24.71	-0.47 (-0.96 to -0.10)	6/92/0 <i>likely trivial</i>

**r* = pre-post tests correlation; Δ = mean differences; 95% CI = confidence interval at 95%; Δ% = relative changes; ES = effect size; G10 = 10% group; G20 = 20% group; CMJ = countermovement jump; SJ = squat jump; MRTD = maximal rate of torque development; RTD = rate of torque development; ANOVA = analysis of variance.

†Repeated measures ANOVA revealed time effect for decreases in 10-m ($p = 0.018$) and 20-m ($p = 0.033$) sprint times and CMJ ($p = 0.019$).

Table 3
Lower-limb lean mass and hamstring and quadriceps maximal strength data before and after training.*

Groups	Pre	Post	r	Δ (95% CI)	Δ%	ES (95% CI)	% Chance rating
Lower-limb lean mass (kg)							
G10	22.09 ± 3.25	22.26 ± 3.15	0.97	0.17 ± 0.81 (-0.40 to 0.73)	0.77 ± 4.22	0.05 (-0.12 to 0.22)	0/100/0 most likely trivial
G20	23.16 ± 3.19	23.31 ± 3.09	0.98	0.16 ± 0.67 (-0.28 to 0.60)	0.71 ± 2.82	0.05 (-0.09 to 0.19)	0/100/0 most likely trivial
Quadriceps MVC (N·m)							
G10	217.62 ± 52.25	207.25 ± 38.67	0.87	-10.38 ± 26.70† (-28.88 to 8.13)	-4.68 ± 12.84	-0.20 (-0.55 to 0.16)	4/79/16 likely trivial
G20	230.22 ± 45.66	208.62 ± 40.80	0.83	-28.13 ± 25.14† (-44.55 to -11.70)	-14.37 ± 12.50	-0.47 (-0.98 to -0.26)	4/95/0 very likely trivial
Quadriceps PT 60°·s ⁻¹ (N·m)							
G10	247.62 ± 39.04	233.62 ± 26.33	0.69	-14.00 ± 28.32 (-33.63 to 5.63)	-6.12 ± 12.32	-0.36 (-0.86 to 0.14)	1/95/3 very likely trivial
G20	246.77 ± 23.96	236.75 ± 19.75	0.87	-8.88 ± 12.62 (-17.12 to -0.63)	-3.70 ± 5.19	-0.42 (-0.71 to -0.03)	1/99/0 very likely trivial
Hamstring MVC (N·m)							
G10	148.12 ± 30.60	138.75 ± 22.73	0.86	-9.38 ± 16.18 (-20.58 to 1.83)	-6.52 ± 11.93	-0.30 (-0.67 to 0.06)	15/75/9 likely trivial
G20	144.88 ± 34.45	163.71 ± 38.05	0.72	12.71 ± 27.71 (-5.39 to 30.82)	7.01 ± 17.46	0.54 (-0.16 to 0.89)	2/96/0 very likely trivial
Hamstring PT 60°·s ⁻¹ (N·m)							
G10	139.50 ± 20.34	133.37 ± 15.51	0.80	-6.13 ± 12.24 (-14.61 to 2.36)	-4.60 ± 9.18	-0.30 (-0.72 to 0.12)	1/97/0 very likely trivial
G20	150.33 ± 33.79	144.75 ± 30.01	0.96	-6.13 ± 10.84 (-13.21 to 0.96)	-3.80 ± 7.53	-0.16 (-0.39 to 0.03)	0/99/0 most likely trivial
Hamstring Ecc PT 60°·s ⁻¹ (N·m)							
G10	180.62 ± 28.01	178.37 ± 15.47	0.78	-2.25 ± 18.74 (-15.23 to 10.73)	-1.02 ± 10.27	-0.08 (-0.54 to 0.38)	0/88/11 likely trivial
G20	193.55 ± 37.17	212.00 ± 32.09	0.86	13.00 ± 20.20 (-0.20 to 26.20)	6.39 ± 9.77	0.49 (-0.01 to 0.70)	0/99/0 most likely trivial

*r = pre-post tests correlation; Δ = mean differences; 95% CI = confidence interval at 95%; Δ% = relative changes; ES = effect size; G10 = 10% group; G20 = 20% group; MVC = maximal voluntary contraction; PT = peak torque; Ecc = eccentric; ANOVA = analysis of variance.
†Repeated measures ANOVA revealed time effect for decreases in quadriceps MVC (p = 0.010).

physically active men by an extent of about 5%. On the other hand, Morin et al. (27) tested 16 male amateur soccer players before and after an 8-week intervention in which they were assigned to either a “very-heavy sled” (80% BM) or a “control group” (who performed only traditional unresisted sprints). The very-heavy sled group presented moderate improvements and the “control group” presented “small” improvements in 5-m sprint times; nonetheless, the difference between groups in the sprint performance was rated as “trivial.” Therefore, at least for a group of soccer players who continually perform resisted sprint training for 11 weeks, it appears that a range of sled loads from moderate-to-heavy (i.e., 45–65% BM) is sufficient and effective to improve 10- and 20-m sprint performance. However, it should be emphasized that these improvements are maximized when the resisted sprint training volume is adjusted based on the new-found velocity-based approach presented herein.

It is also important to note (and compare) the magnitude of relative increases in sprint velocity observed in the current study. Using this novel velocity-based model, it was found a 5.5% of decrease in 10-m sprint time for G10, who performed a total sprint distance of, on average, 675 m (380–880 m) across 10 training sessions, which is substantially lower than the training volume prescribed in previous studies which already reported similar increases in sprint performance (i.e., ~1,400 m during 12 sessions with ~13% BM in rugby players; and ~850 m during 16 sessions with ~45% BM in physically active men) (17,21). These similar improvements in sprint performance should be viewed with caution because of the differences in sample characteristics (i.e., soccer players vs. rugby players and physically active men). Nevertheless, the optimized gains in the current study may be attributed to the individual monitoring of velocity loss, which is the most important methodological aspect of this investigation. Therefore, based on our data, it is possible to suggest that, when applying moderate-to-heavy (45–65% BM) sled training in soccer players, the individual monitoring of velocity loss throughout successive sprint efforts is critical to achieve superior performance enhancements. But importantly, lower thresholds of velocity loss (i.e., up to 10%) should be used to maximize sprint adaptations.

A previous study indicated that higher magnitudes of velocity loss may optimize muscle hypertrophy (29) during traditional resistance training; however, the present study did not identify this tendency during resisted sprint training. Besides the differences in training procedures, it is plausible to speculate that the absence of changes in lower-limb lean mass occurred because the athletes were also involved in traditional soccer training and official matches, which may potentially affect the degree of morphological changes (14). Moreover, although lengthened hamstring RTD showed positive correlations with sprint velocity and horizontal force output in soccer players (16,20), the current study did not find positive changes in this variable at post-test. In fact, there were negative changes in RTD (especially in G20), contrasting the positive changes in sprint performance. Therefore, the present training model was not able to improve RTD, perhaps because of specificity of training and evaluation. It is likely that “traditional” strength-power training strategies may be more recommended to counteract the possible decrements on neuromuscular function (especially RTD), which usually occur in response to official matches and soccer-specific training practices (16,24), and to improve other speed-power-related capacities in soccer athletes (24,25).

The present study has some limitations. First, there was not a control group. The soccer club did not accept that a non-intervention group could be deprived of the possible training benefits. An unloaded group could be a viable strategy, but the

velocity-based approach would not be possible because the volume to achieve a decrease of 10% or 20% in maximum velocity during traditional sprints would be considerably higher compared with a moderate-to-heavy sled. In fact, this alternative was examined through a pilot study. Second, different sled intensities were not tested to confirm that moderate-to-heavy is more effective than, for example, light sled intensities (e.g., from 5 to 20% BM). Finally, the athletes had different field positions/demands on the pitch and were exposed to other stimuli such as traditional soccer training and matches throughout the intervention. Thus, the influences on the outcomes cannot be neglected. However, it is important to note that both intervention groups were balanced on players field positions and minutes played which could be even considered a strength of the present study. In fact, only the velocity-based sled training was different between groups and, importantly, there was no difference between groups in the number of minutes played. Therefore, this is the first study investigating the effects of different magnitudes of velocity loss during moderate-to-heavy sled training in elite team-sport players. Our findings advance the body of knowledge regarding resisted sprint training and lead us to propose new interventions based on different magnitudes of velocity decreases. This novel approach considers the individual capacity of each athlete to achieve and maintain optimal levels of velocity while exercising, which seems to be a key factor in resisted sprint training prescription (1). Future research comparing different magnitudes of velocity loss and sled loads is clearly warranted to extend and confirm our findings.

Practical Applications

The sled towing exercise is widely used in the sprint training practices, especially in elite soccer scenarios (22,27). Nonetheless, there is an emergent need for scientific data regarding their chronic effects on soccer athletes. Our findings advance the body of knowledge on resisted sprint training, because an unprecedented velocity-based training approach was used, in which the magnitudes of velocity loss were tailored and assessed for each resisted sprint bout. Based on our data, it is possible to suggest that, during sled towing, the use of lower magnitudes of velocity loss (i.e., up to 10%) associated with moderate-to-heavy loading intensities (i.e., from 45 to 65% BM) throughout 11 weeks may induce superior adaptations in unresisted sprint performance in professional soccer players (when compared to higher decreases in resisted sprint velocity). Strength and Conditioning coaches and sport scientists should be aware of this potential and critical tendency when designing resisted sprint training programs for their athletes. In fact, during moderate-to-heavy sled training (45–65% BM), lower magnitudes of velocity loss (10%) produced greater gains in sprint performance compared with greater magnitudes of velocity loss (20%). Furthermore, 20% of velocity loss during resisted sprints provoked harmful effects on some mechanical muscle parameters of professional soccer players.

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