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Postactivation Potentiation Effect of Heavy Sled Towing on Subsequent Sprints

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Abstract

Williams, JJ, Herron, RL, Spradley, B, and Saracino, P. Postactivation potentiation effect of heavy sled towing on subsequent sprints. *J Strength Cond Res* 35(5): 1229–1233, 2021—Recent research supports heavy sled towing as a tool used to improve subsequent sprints as part of postactivation potentiation (PAP) protocols. The purpose of this study was to examine the effect of heavy sled towing using a velocity decrement (V_{dec}) on subsequent unloaded sprinting in high school football (soccer) athletes sprinting on artificial turf. A sled load equating to a 40–50% V_{dec} range was used (66–70% body mass). Fifteen ($n = 9$ boys and $n = 6$ girls) high school football players volunteered for this study. The sled-towing intervention consisted of a dynamic warm-up, 3 submaximal sprint efforts (50, 75, and 95%), and 3 maximum speed 15-m sled sprints, separated by 2-minute rests, of which the fastest time was recorded for analysis. Peak preintervention 15-m baseline sprint times were compared with peak post sled-towing 15-m sprint times using a paired samples *t*-test. Thirteen of 15 athletes ran faster peak post sled-towing sprint times than peak preintervention baseline sprint times (9 boys and 4 girls). On average, peak post sled-towing sprint times (2.60 $\pm$ 0.10 seconds) were 0.10 seconds faster ($p < 0.0001$; Cohen's $d = 0.92$) than peak preintervention baseline sprint times (2.70 $\pm$ 0.09 seconds). This research established that sled-towing protocols using loads corresponding to V_{dec} of 40–50% significantly improved subsequent sprints in high school football (soccer) athletes running on artificial turf.

Key Words: acceleration, velocity decrement, sprinting, PAP

Introduction

Short-range sprint speed (≤20 m) could be the most important athletic quality in field-sport athletes (13). In an effort to develop faster sprint speed in athletes, strength and conditioning (S&C) coaches often implement external resistance during training (6,13,17,21,22). External resistance includes weighted sleds, sophisticated tension devices (e.g., 1,080 Sprint), weighted vests, and parachutes. External resistance devices are worn by the athletes or attached at the waist or chest by a cord (13). In this article, sled towing will be used to define external resistance.

Although uncommon, researchers have used heavy sled-towing protocols using a large percentage of body mass (BM) during interventions (e.g., 75% BM) to acutely improve subsequent sprint speed (31). Repeated muscular contractions, working against moderate to heavy resistance, which do not result in fatigue,have been found to temporarily increase subsequent force production in dynamic movements (10,19). This phenomenon is known as postactivation potentiation (PAP), a method using maximal and near-maximal contractions to enhance subsequent contractions, resulting in greater force production (10). Although the physiological underpinnings explaining PAP are not clearly understood, there is evidence that the method is effective to improve performance in athletes (19). Some researchers pose that there is an increase in phosphorylation of myosin light-chain molecules in muscle tissue causing an increase in sensitivity to calcium, resulting in stronger muscle contractions (28). Another possible mechanism is an increase in the recruitment of higher order motor units (19).

Typically, the PAP protocols occur in the weight room using preload compound movements between ≈60 and 85% 1 repetition maximum (RM), followed by an explosive movement, such as jumping and sprinting (19). There are many factors that influence fatigue and potentiation, including strength, training status, movement similarity, exercise intensity, fatigue, and length of rest period (19). These factors have yielded equivocal results and recommendations, potentially due to individual training status (30). A meta-analysis of 141 effect sizes spanning 32 studies indicated moderate intensity (60–84% 1RM) is most effective intensity for potentiation of subsequent explosive movements (30). These data provide compelling evidence that PAP is useful, so long as fatigue is minimized.

An often misunderstood application of sled towing is the accounting (or lack thereof) for surface friction. In sled-towing exercises, the total load placed on the athlete derives from the friction force between running surface and the base of the sled. Friction coefficients explain this interaction. Varying surfaces have different coefficients, and thus affecting the speed of the sled. Using traditional BM recommendations is, therefore, impractical and is not a translatable representation of the total load. For example, a sled loaded with 1,000 pounds may be immovable on a dry artificial surface but may slide easily on the same surface when wet. The weight of the sled and load weight did not change but the friction coefficient did. Because of the friction-force interplay, velocity decrements may provide more utility in sled-towing load estimations (18).

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Correction: When originally published, Robert L. Herron's name appeared incorrectly as Robert Herron.

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Whelan et al. (29) examined the acute PAP effects of sled towing on subsequent sprint performance. Twelve, active men towed sled loads of 25 and 30% BM for 3 repetitions with rest periods of 1, 2, 4, 6, 8, and 10 minutes. Step rate, contact times, and 10-m sprint speed were the variables studied. The researchers concluded that resisted sprinting did not acutely improve subsequent sprint performance within their design (29). However, this investigation occurred on a synthetic track surface; a surface that Linthorne and Cooper (18) indicated had the highest friction coefficient or the highest force between the sled and the ground (18). Moreover, a recent meta-analysis examining the effectiveness of sled towing on sprint performance concluded that rigid surfaces, such as artificial turf, alter sled-towing resistance relative to comparable sled loads on other surfaces (1). Therefore, the differences in friction between varying surfaces may alter the stimulus and subsequent fatigue.

There is evidence supporting that heavy sled towing improves both direction and magnitude of force output during sprinting. Researchers have indicated that training with very heavy sled loads (≈80% BM) chronically improves horizontal force output (25). This is important because the ability to apply force horizontally during acceleration is closely correlated ($R^2 > 0.683$, $p < 0.018$) to faster sprint performance (23). Horizontal impulse has also been found to be a moderately strong indicator ($R^2 = 0.61$, $p < 0.001$) of sprint velocity (13). Moreover, the horizontal orientation of force was found to be more important than the total force during sprint acceleration (24), and a one *SD* increase in relative vertical impulse has been found to predict an increase of $0.14\ m\cdot s^{-1}$ (13) or slower running. In a study of sprint mechanics in world-class sprinters, it was indicated that the best sprinters produce greater horizontal force per unit of body mass at any velocity (26). In addition, a different study compared sled-towing groups using 10% BM resistance, 30% BM resistance, and one unloaded group (14). The researchers concluded that the heavier sled-towing group generated higher demand of horizontal impulse production and higher levels of horizontal force application (14).

Skilled sprinters accelerate more quickly than unskilled sprinters for many reasons, such as a greater range of joint extension, stronger hip extensors, faster reaction times, greater lower extremity elasticity, less total-body center of gravity vertical fall, and greater horizontal force and impulse (11). Some of these factors mentioned by Harland and Steele are attributed to differences in the rate of force production (11). Lockie et al. (20) attributed improvements in acceleration in free sprint training to improvements in horizontal and reactive power. Cross et al. (6) indicated that heavier sled-towing loads (78–82% BM) are more effective than lighter loads to acutely achieve peak power, average power, and horizontal force output in recreational athletes during sled towing. It should be noted that mechanical power has been strongly correlated ($R^2 = 0.850$, $p < 0.01$) with mean 100-m speed (23). An important secondary finding by Cross et al. shows that these BM loads equated to approximately 50% velocity decrement (V_{dec}) and provides a reference point for coaches using heavy sled loads (6).

In summary, the rate of force production, degree of force production, direction of force, and power production influence sprinting speed and acceleration ability (6,11,13,20,23,24,26). Moreover, heavy sled towing has been indicated to improve direction of force and greater peak and average power (6,25). Therefore, hypothesizing that a heavy sled-towing PAP protocol using a V_{dec} to limit fatigue and potentiate subsequent sprints is not unreasonable. This is a worthwhile posit to investigate because ubiquitous agreement for sled-towing loading parameters currently does not exist. Previous researchers have recommended lighter-sled loads (<20% BM) to enhance sprint performance as opposed to heavier loads (21,22). Heavier loads have been cited to cause disruptions in sprint kinematics, such as decreased stride frequency and length, increased ground contact time, trunk lean, hip flexion (17,22), and loss of velocity (2). Therefore, this intervention seeks to bridge the gap among conflicting recommendations. To the best of our knowledge, no other study has investigated the acute impact of a PAP sled-towing protocol using a 40–50% V_{dec} on subsequent sprint performances. We hypothesized that heavy sled-towing loads between 40 and 50% V_{dec} will significantly improve peak post sled-towing sprint times compared with peak baseline sprint times.

Methods

Experimental Approach to the Problem

A repeated measures, preintervention vs. postintervention design was implemented to investigate the acute impact of a PAP protocol, prescribed to elicit a 40–50% V_{dec}, on 15-m sprint speed. The subjects completed 3 visits. The first visit included 3 sprints from which the best attempt was used as the preintervention performance indicator for analyses. The second visit was used to set the individualized sled-towing resistance that would be later used as the PAP intervention. The third visit included the PAP intervention and 3 sprints from which the best attempt was used as the postintervention performance indicator for analyses. The project spanned a total of 11 days.

Subjects

The study was approved by the U.S. Sports Academy's Institutional Review Board (IRB). All subjects were required to complete parental assent documentation before participating in the study. In addition, once parent assent forms were collected, subjects were informed of potential risk and provided with a signed written consent document as required by the IRB process. The risks and benefits were explained, and it was emphasized that their participation in the experiment was strictly voluntary and their willingness to participate in the study did not influence their standing on the team in any way.

To avoid influencing the subjects' day-to-day school activities, they were not asked to avoid any kind of specific activity (e.g., lower-body resistance training) nor avoid consumption of food, water, or ergogenic aids, such as caffeine.

Subjects were recruited from a varsity, high-school football (soccer) program (male and female teams) in the Southeastern United States. A total of 15 subjects (9 boys and 6 girls, aged 16–18 years) took part in this study. General descriptive statistics are shown in Table 1. As members of their varsity team, all subjects had at least 2 years of regular resistance and sport training.

Table 1

Descriptive data for the subjects are listed below: The mean (±*SD*) body mass (kg), squat max (kg), and relative strength (squat max/BM kg) values for subjects (*N* = 15).*

	n	Body mass (kg)	Squat max (kg)	Relative strength ($kg\cdot kg^{-1}$)
Female	6	56 ± 6	99 ± 18	1.76 ± 0.24
Male	9	71 ± 12	121 ± 24	1.78 ± 0.26

*BM = body mass.

Thus, they are not untrained athletes rather these athletes had consistent exposure to compound lifts in a structured S&C environment.

Procedures

The subjects completed 3 visits within an 11-day period, at the same time of day (3:00 PM after school). Two days separated visit 1 from visit 2, and 1 week separated week 2 from week 3. All of the performance testing took place in an indoor facility, on artificial turf, and was preceded by a dynamic warm-up. The 15-minute dynamic warm-up included sprint mechanic drills, followed by a period of 3 submaximal sprints (at 50, 75, and 95% efforts). A 3-minute recovery period always took place after the warm-up and before the testing activity during each visit. Each 15-m sprint time was assessed using a Freelap Timing System (BLE112, Switzerland). The BLE112 is a timing system requiring the athlete to wear a small chip (FXChip) clipped on the waistband of the subject's pants, near the navel. The FXChip reacts to a magnetic field emitted by transmitters placed at the distances the researcher seeks to measure. The accuracy of the system is ±0.02 seconds, which is similar to single-beam photocell timing accuracy, and validated for unloaded and loaded sprint timing (7). Results are transmitted to the system's accompanying mobile phone application.

For sled trials, subjects towed a 14-kg steel sled (Speedster, Gulf Shores, AL) and calibrated Olympic barbell weights to reach the resistance needed to elicit a 40–50% V_{dec}. A waist belt (Speedster, Gulf Shores, AL) harness was attached to the sled using carabiner clips. The sled load required to elicit a 40–50% V_{dec} was sought through trial and error, during the second visit. Each subject was originally given a load of ≈70% BM and the weight was adjusted until the load elicited a 40–50% V_{dec} relative to their peak baseline sprint times. In other words, through a trial and error process, each athlete towed different loads that caused sprint time to be 40–50% slower than an unloaded 15-m sprint. For example, if 15-m sprint times were 2.3 seconds, a 50% V_{dec} would be 4.6 seconds. The athletes were positioned in a staggered stance, and then performed loaded 15-m sprints until the decrement was found. On average, 2 repetition attempts were enough to find a 40–50% V_{dec}. Two-minutes of rest was given after each sprint. Cross et al. (6) indicated a 50% V_{dec} to correspond to 78–82% BM, so loads for the first test were prescribed at 70% BM, slightly less due to the immaturity of the athlete (6). This decision is supported in recent research by Cahill et al. (5) who found a 50% V_{dec} reliable to prescribe sled-towing loads between 45 and 85% BM for high school athletes.

During visit one, BM measurements were collected and relative strength was calculated by dividing traditional 1RM barbell squat maximums by BM. All squat maximums were tested by the coach exactly 3 weeks before the intervention. Baseline sprint times (15 m) were recorded for all athletes. The athletes were instructed to give maximal effort and were encouraged to push through the last few steps of the sprint to produce maximal sprinting. During visit 2, the sled-towing load was tested as described above. The third visit included the PAP intervention. After the warm-up, weighted sleds were hooked up to the subjects with their predetermined PAP loads for a total of 3 sled-towing sprint repetitions. Between PAP repetitions, research assistants were instructed to unhook the athlete's belts after each sprint and tow the sled back to the starting line, to prevent the accumulation of fatigue and give the athletes true-rest periods. The athletes walked back to the starting line and were allowed to walk around to recover before the next repetition. This is an important consideration for practical use because PAP protocols are only effective if fatigue can be minimized.

During the third visit the subjects executed the PAP sled-towing sprints at the loads corresponding to an individual 40–50% V_{dec}. There were 3 PAP repetitions with 90-second rests between each. At the conclusion of the sled-towing protocol, 3 unloaded maximal 15-m sprints were completed with 2 minutes of rest between each sprint. The best peak baseline sprint times after each of 3 rest periods was used in comparison with the best peak post sled-towing sprint times.

Statistical Analyses

Data were first entered and organized in Microsoft Excel (2018). Descriptive statistics, effect-size calculations, correlations, and one-tailed paired samples *t*-tests were calculated in Excel. SPSS 26 (SPSS Inc., Chicago, IL) was used to calculate reliability statistics for baseline sprints using intraclass correlation coefficient (ICC), based on a mean rating ($k = 3$), absolute agreement, 2-way mixed-effects model and interpreted relative to the thresholds reported by Koo and Li (15).

The one-tailed, paired samples *t*-test was used to compare peak baseline sprint times to peak post sled-towing sprint times. An alpha = 0.05 was used as a decision threshold. To further examine differences between baseline and postpotentiation sprints, effect size was calculated using Cohen's *d*. Observed power was calculated using G Power 3.1 software (8).

Results

Subject baseline descriptive information can be found in Table 1. The ICC showed good reliability (ICC = 0.96; 95% confidence interval [CI] [0.90–0.98]) for the baseline 15-m sprint performance measure (15).

The results of a one-tailed, paired samples *t*-test indicted a mean difference between peak baseline sprint times and peak post sled-towing sprint times ($p < 0.001$, observed power = 0.99). A Cohen's $d = 0.92$ indicated a moderate to large magnitude of effect size, when subjects are categorized as recreationally trained (range $d = 0.8$–1.5) or highly trained (range $d = 0.5$–1.0), respectively (9,12,27). In addition, a Pearson correlation ($r = 0.73$) revealed a strong linear association between both means (4). A mean difference between peak baseline sprint times (2.70 ± 0.09 seconds) and peak post sled-towing sprint times (2.60 ± 0.10 seconds) was 0.10 seconds, 95% CI [0.06–0.14]. Table 2 illustrates the individual subject responses, comparing peak baseline sprint times to peak post sled-towing sprint times. Of the 15 subjects, 13 ran faster after sled towing compared with baseline. Average sled loads for boys were 70% BM and 66% BM for girls.

Discussion

The results of this study support the use of the heavy sled-towing PAP protocol (approximately 40–50%V_{dec}) to acutely improve 15-m sprint performance in high school football athletes running on artificial turf. The sled loads ranged from 66 to 70% BM with a corresponding average V_{dec} of 43–44%.

On average, the athletes ran 0.1 seconds faster after the PAP intervention. Of the 15 athletes, 13 of them ran faster after sled-towing sprint times. Both athletes who ran slower were girls, one with notably weaker relative strength compared with the female

Table 2
Individual and mean data for baseline sprint time, post-PAP sprint time, and the delta (post − base).*

Subject's identifier	Baseline sprint time (s)	Post sprint time (s)	Delta (post − base)
1	2.79	2.67	−0.12
2	2.71	2.54	−0.17
3	2.74	2.54	−0.2
4	2.72	2.73	0.01
5	2.71	2.75	0.04
6	2.69	2.63	−0.06
7	2.63	2.56	−0.07
8	2.59	2.49	−0.1
9	2.9	2.82	−0.08
10	2.75	2.61	−0.14
11	2.74	2.61	−0.13
12	2.54	2.52	−0.02
13	2.58	2.45	−0.13
14	2.68	2.56	−0.12
15	2.76	2.56	−0.2
Mean	2.70	2.60	−0.10
SD	0.09	0.10	0.07

*Paired sample *t*-test showed a mean difference ($p < 0.001$), with post-PAP sprint times being 0.10 seconds faster, on average (Cohen's $d = 0.92$). In addition, 13 of the 15 subjects ran faster after the intervention.

mean (−0.43 BM) yet the other with higher relative strength (+0.13 BM). However, the focus of this study is on providing information on an effective method of sled towing to improve linear speed not to compare sex differences.

These results were similar to the findings from Wong et al. (32) that indicated sled loads of 30% BM, potentiated 0–5-m sprint times by 0.08 seconds when compared with baseline sprints (32). It should be noted that the athletes in Wong's study ran on artificial turf surface similar to the subjects in this study (32). Whelan et al. (29) also used sled loads equating to 25–30% BM and found no main effect for PAP on subsequent 10-m sprints (29). However, this investigation occurred on a synthetic track surface, a surface that some researchers indicated the highest friction coefficient or highest force between the sled and the ground (18). In addition, Whelen et al. (29) also used a shoulder harness, an attachment point researchers have cited as inferior to the waist attachment because of greater kinematic alterations and significantly less horizontal impulse output (3,29). The findings of this study may give more credence to using a V_{dec} instead of BM to mitigate the possibility of increased fatigue due to unknown friction forces (29).

Winwood et al. (31) cited the importance of using sprint decrements stating, "Practitioners should be advised that prescription of training load based on decrement in sprint velocity may be the best approach to determine loading for athletes" (31 pg. 1248). These researchers reported significant time improvements in subsequent 15-m sprints after PAP protocols using a BM sled load of 75% (31). Moreover, these researchers tested on indoor artificial turf. A recent meta-analysis concluded that rigid surfaces, such as artificial turf, enhance the effect of sled towing (1). This could be because of the lower friction force between the sled and the surface that resulted in less fatigue. Accounting for friction and thus limiting fatigue is a strong possible contributor to improvements in sprint times when using a V_{dec} in sled-towing PAP protocols.

The change in sprint kinematics resulting from heavier sled loads may have also led to beneficial kinetic and kinematic outcomes in this study. Kinematically, sled towing creates a noticeable increase in the angle of body lean during the activity (29,31). This lean creates the opportunity to produce more force horizontally because the angle of lean is highly correlated ($r = 0.93$) to the direction of ground reaction forces (16).

The potential factors that led to time improvements are likely increased horizontal force output because of improved orientation of body position, improved total force output (e.g., power, impulse) because of PAP, and adequate fatigue mitigation. Mitigating fatigue could have been achieved by selecting shorter sprint distances but most likely is due to using a V_{dec} and accounting for friction.

The main limitation of this study was the inability to control free-living variables that may have impacted one's performance (e.g., nutrition, caffeine intake, sleep, uniform footwear, schoolwork, and hydration). It is possible that outside factors influenced the outcomes, within this study design. One notable variable was the inability to attain first-hand 1RM squat maximum data correlated with peak post sled-towing sprint times. Coach-reported data could be accurate but limit the inferences one can make based solely on those data. In addition, fatigue and effort are legitimate concerns.

Because all daily activity was not controlled, there is no way to determine the degree of fatigue the athletes experienced each day during the 11-day period. For example, athletes could have participated in club football (soccer) matches the weekend before baseline sprints and performed less optimally. Finally, athlete effort is another variable that could not be controlled. For example, some athletes may not have experienced optimal results due to poor effort, but one could argue this is an issue in every human performance study. As such, researchers and practitioners should interpret these results within context. However, it should be noted that the athletes were encouraged during recruitment to treat data collection days just like they would any other day and report to seventh period athletics like normal. Thus, these were typical, off-season school days during which the subjects did not participate in high-intensity physical activity on the days of testing, minimizing the impact of potential fatigue on 3 short-distance sprints.

Because of logistical constraints, a study design that included a parallel control group, placebo, or counter-balanced, crossover design could not be implemented. Thus, the research design could be considered a limitation.

Practical Applications

Sled-towing loads that correspond to a 40–50% V_{dec} potentiated subsequent sprints in high school football athletes running on artificial turf. Much has been written about the efficacy of sled towing to improve running speed but this study adds to a growing body of research that supports its use as a S&C PAP method (31,32). Furthermore, these findings support the use of velocity decrement as a way to prescribe sled loads for high school athletes running on artificial turf and potentially independent of running surface. However, as only one surface was tested in this study, this is merely speculation. Future work should investigate the usefulness of V_{dec} on multiple running surfaces.

The results of this intervention provide compelling evidence that a PAP protocol, which includes 3 repetitions of sled towing eliciting a 40–50% V_{dec}, is an effective method to acutely improve short-sprint ability in weight-trained, high school athletes when running on artificial turf.

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