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ORIGINAL ARTICLE

Comparative effects of motorized versus traditional sled training on speed, agility, and power in collegiate football athletes over eight weeks

Trent Yamamoto . *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Chobanian and Avedisian School of Medicine. Boston University. Boston, MA, United States of America.
Phillip Goldman. *Baylor College of Medicine. Houston, TX, United States of America.*
John Taylor. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Trinabh K. Sahni. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
August E. Blatney. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Ross J. Lechner. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Jacob Bright. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Dominic M. Benna. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Dylan Cho. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Aidan Torres. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Thalia H. Nguyen. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Eric V. Neufeld. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Northwell Orthopedics. New Hyde Park, NY, United States of America.
Long Island Jewish Medical Center/North Shore University Hospital. New Hyde Park, NY, United States of America.
Mitchell S. Mologne. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
Washington University School of Medicine. Saint Louis, MO, United States of America.
Brett A. Dolezal. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*

ABSTRACT

Training utilizing a resistance sled has been shown to confer considerable improvements in athletic performance across speed, strength, and power metrics. However, most available training protocols only investigate sled pushing and/or pulling in isolation, with none incorporating lateral movement (i.e., multiplanar movements). The objective of the present study is to determine the efficacy of a novel sled utilizing motorized resistance to improve performance measures while using a comprehensive training program using multiplanar exercises. Forty-eight healthy collegiate male football players were recruited for this 8-week, randomized control trial with three weekly training sessions. Participants were randomized into one of two training groups utilizing either a motorized resistance sled training apparatus (MRS) or a traditional resistance sled training apparatus (CONT). Improvements in countermovement jump height, peak power, 20-meter sprint, and 5-10-5 Pro Agility Test performance were significantly greater in MRS compared to CON ($p < .003$, d = 1.1; $p < .002$, d = 1.0; $p < .001$, d = 1.9; $p < .001$; d = 1.9; $p < .005$; d = 0.9, respectively). These findings are the first to demonstrate the efficacy of a novel motorized resistance sled with a training protocol encompassing a variety of multiplanar movements to improve performance measures related to American football.
Keywords: Performance analysis, Resisted sled push and pull, Speed, Strength, Power, Conditioning.

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Corresponding author. *Airway and UC Fit Digital Health-Exercise Physiology Laboratory. David Geffen School of Medicine. University of California Los Angeles. Los Angeles, CA, United States of America.*
E-mail: sebastian.schroeder@ovgu.de
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INTRODUCTION

Performance in American football is heavily influenced by an athlete's speed, strength, and power (Robbins & Young, 2012). These characteristics are fundamentally vital to success on the field irrespective of position and different skill sets (Robbins, 2011). The National Football League (NFL) has thus utilized a variety of assessments to evaluate an athlete's physical measures at their annual scouting combine. With strong correlations between many of these measures and in-game performance (Vincent et al., 2019; Hedlund, 2018), such as 40-yard dash speed and rushing statistics (Parekh & Patel, 2017), improving the physical attributes of football athletes has become a key focus for training across all levels of the sport.

Over the years, resisted sled training (RST) has emerged as an effective training modality to improve sprint speed and acceleration (Petrakos et al., 2016). RST is posited to improve performance by increasing an athlete's horizontal force production (Cahill et al., 2019). Several protocols incorporating RST, mainly through sled pulling, have yielded encouraging results. In a six-week RST protocol with professional rugby players that utilized loads equivalent to 12.6% of their body mass, 10 and 30-meter sprint performance was significantly improved compared to a traditional sprint training protocol (West et al., 2013). Similarly, a nine-week RST protocol for soccer players, using a heavy sled that induced a 50% velocity decrement, maximized external lower body power while improving 10-meter split times more effectively than traditional training methods (Lahti et al., 2020).

There is, however, a considerable amount of variability in the outcomes of RST that has been attributed to methodological inconsistencies. While sled loading is typically prescribed as a percentage of body mass, this strategy fails to account for individual and athlete-specific differences in technical ability, strength, and power (Bentley et al., 2014). Consequently, discrepancies in relative load between athletes can lead to unpredictable responses to RST (Cross et al., 2017). Several studies utilizing sled loads based on body mass (12.6 and 30%, respectively) found no significant differences in sprint time improvements between RST and other conventional training modalities (Lockie et al., 2012; McMorrow et al., 2019). Beyond loading concerns, the vast majority of RST protocols have investigated either sled pulling or pushing in isolation, rarely incorporating both exercises in a unified regimen. Given that sled pushing has been associated with acute sprint performance enhancements (Pino-Mulero et al., 2024), examining the effects of both exercises in tandem warrants further investigation.

In light of the shortcomings of conventional RST, a novel resistance modality may offer a promising alternative. Through the use of electromagnetic motor-driven resistance, motorized sleds can provide a wide range of resistance levels that allow them to be adaptable to athletes with diverse abilities. The incorporation of wheels further enhances functionality by introducing multi-directional movements, enabling training in the transverse plane. Consequently, a sled leveraging this type of resistance could serve as a more versatile and effective training tool to improve athletic performance.

To our knowledge, there is no available research that has investigated the effects of training with a motorized resistance sled that incorporates pushing, pulling, and lateral movements. Thus, the primary objective of the present study is to examine the efficacy of a motorized resistance sled to mediate improvements in speed, agility, and power over an eight-week training regimen in comparison to traditional RST in collegiate football players.

METHODS

Participants
Forty-eight apparently healthy male collegiate football players from a college in Southern California volunteered for this study. Inclusion criteria included individuals of 18-27 years of age with a history of resistance training with a minimum of 12 sessions of monthly exercise within the past 12 months. Exclusion criteria included the presence of any significant medical diagnosis such as musculoskeletal, cardiovascular, metabolic, pulmonary, and/or other disorders that limit the ability to exercise or increase the risk of adverse cardiovascular events while exercising. Screening for the use of any performance enhancing drug known to enhance anabolic responses was also used for exclusion purposes. All exploratory participants from UCLA provided written informed consent while ethical approval was obtained from UCLA (IRB: 11-003190). Research practices were conducted in accordance with the ethical principles documented in the Declaration of Helsinki. Participants completed a pre-participation physical activity readiness questionnaire (PAR-Q) and an exercise history questionnaire. Sample size of n = 48 was calculated based on a priori power analysis using the baseline to 8-wk counter movement jump improvement of 5 cm reported from a pilot study using five resistance-trained, collegiate-aged males of similar design in our research laboratory assuming a = 0.05 and b = 0.2.

Study design
This was an 8-week, single-blinded, randomized control trial using a parallel research design. Study participants were randomly placed 1:1 into one of two groups that were incorporated into an off-season strength and conditioning program: the intervention, using a motorized resistance sled training apparatus (MRS) or the control, a traditional resisted sled training apparatus (CONT), by an investigator independent of the recruitment of participants using an online-generated random number program. Allocation was concealed with the use of consecutively numbered envelopes. The participants worked out thrice weekly for 8-weeks (for a total of 24 sessions), between 45-60 minutes per session. An 8-week trial was selected to ensure a training adaptation from both research arms. To prevent confounding variables, participants were asked to refrain from additional resistance-type or high-intensity anaerobic training for the duration of the study. All of the field-based assessments and training sessions were monitored at an off-site training facility that employed one researcher consulted under the guidance of the UC Fit Digital Health - Exercise Physiology Research Laboratory at UCLA lab director. Dietary intake and macronutrient portions were not controlled apart from the requirement of not starting a dietary supplement or weight loss/gain diet that might affect total and fat-free body mass.

Training intervention
Both training intervention groups were incorporated into the players' traditional off-season program. The 8-week off-season strength and conditioning program is proprietary and has been successfully implemented each of the past 5 years. The overarching goal, according to the strength and conditioning coaches, was to "*maximally improve strength, speed, acceleration, power, agility and core stability*" by utilizing a multitude of training schemes and equipment in an indoor-outdoor facility with 40 yards of artificial turf adjacent to the weight room.

The interventions were scheduled over an 8-week period. During this window, the participants' normal training program continued. The sled training programs were broken up into two repeated block periodization schemas and were identical other than the sled apparatus used. Once the first four-week block was complete, this was repeated with adjusted exercise loadings in the subsequent block.

Five resisted sled exercises were integrated into every training session, making use of both pushing and pulling exercises that allowed for different variations of external loads to be applied during sprinting and sprinting derivatives. Operationally, resisted sled pulling and pushing differed primarily in how they provided a posterior and anterior loading stimulus on the athlete. All attempts were made to match identical starting loads relative to the athlete (ie. starting at level 1 intensity versus level 2 intensity and increasing thereafter during the second block) for each resisted sled exercise for every session. Table 1 shows the 8-week training program including a brief description of the resisted sled exercises.

Table 1. 8-week, two repeated block periodized resisted sled training schema using smart-resisted apparatus (MRS) and traditional resisted sled apparatus.

Sled Push	**Details:**
• Block 1 (Wk #1-4, sessions 1-12): 8 reps x all-out-sprint 20 sec @ level 1 intensity (150 lbs) - 20 sec rest between reps. • Block 2 (Wk #5-8, sessions 12-24): 8 reps x all-out-sprint 30 sec @ level 2 intensity (300 lbs) - 15 sec rest between reps.	• Place hands on sled poles, straighten arms out overhead, engaging the core – alternate by holding bar lower or higher on every other rep.
Sled Bunny Hops	**Details:**
• Block 1 (Wk #1-4, sessions 1-12): 4 reps x 25 meters @ level 1 intensity - 20 sec rest between reps. • Block 2 (Wk #5-8, sessions 12-24): 6 reps x 35 meters @ level 2 intensity - 15 sec rest between reps.	• Place hands on sled poles, straighten arms out overhead, engaging the core – alternate by holding bar lower or higher on every other rep. • With feet hip-width apart, sit the butt back and bend the knees. • Push sled as you jump forward, extending the hips. • Bend the knees and sit the butt back again when landing, making sure to push with the glutes to power the hops forward.
Sled Fighting	**Details:**
• Block 1 (Wk #1-4, sessions 1-12): 4 reps x 30 sec @ level 1 intensity - 20 sec rest between reps. • Block 2 (Wk #5-8, sessions 12-24): 6 reps x 45 sec @ level 2 intensity - 15 sec rest between reps.	• Using a rectangular space, move the sled forward a few steps, the turn it, move diagonally, then rotate it around and move the other direction. • Pivot the sled, push and pull, moving it only a few steps in each direction. • Movements should be quick and short around the space, engaging core.
Sled Drag & Reverse Sled Drag	**Details:**
• Block 1 (Wk #1-4, sessions 1-12): Alternate between the two exercise iterations for 4 reps x 20 sec @ level 1 intensity - 20 sec rest between reps. • Block 2 (Wk #5-8, sessions 12-24): Alternate between the two exercise iterations for 6 reps x 45 sec @ level 2 intensity - 15 sec rest between reps.	• Sled behind (for posterior chain): Using handles attached to the sled hook, with arms straight down by the sides while leaning forward with back flat and core engaged, walk with stomping steps forward. • Facing sled (for anterior chain): Using handles with the arms straight out, sink into a higher squat, keeping chest up and back flat, walk backward with big or smaller and quicker steps.
Lateral Sled Drag	**Details:**
• Block 1 (Wk #1-4, sessions 1-12): 4 reps x 20 meters @ level 1 intensity; 20 sec rest between reps. • Block 2 (Wk #5-8, sessions 12-24): 6 reps x 40 meters @ level 2 intensity; 15 sec rest between reps.	• Using a rope while standing with one's side to the sled, step with the foot furthest from the sled before stepping to the side with the other foot to move laterally. • Do not rotate open toward the sled, only shuffle laterally. • Complete the drag one direction and then switch directions using the other foot and hand. • Changing pace and stride length throughout is ideal.

Resisted sled apparatuses: Traditional (CON) vs Motorized (MRS)

For the control (CON), a traditional resistance sled (Dog Sled 1.2, Rogue Fitness, Columbus, OH, USA) was used. The standard speed sled design featured upright bars for pushing, as well as holes and hooks for dragging straps or pulling, compatible with a multitude of optional attachments. Used traditionally on grass or turf, this sled was constructed with 2-inch-by-3-inch, 11-gauge steel with 0.25-inch plate steel in a 40” L x 24” W, 103 lb frame with the capacity to hold up to 500 lb of additional weight.

The intervention featuring a motorized resistance sled (MRS) is a four-wheel all-terrain, push/pull training sled with dual pegs capable of holding up to 1000 lbs of additional weight (Smart Sled, Mach Fitness Lab, Orange County, CA, USA). There are upright ergonomic cambered-shaped handles and a tow hook for pulling and harness workouts. The 45” L x 40” H x 31 W,” 250 lb hard steel frame provides unique multi-directional workouts by utilizing dual electromagnetic resistance front-wheel motors for customizable intensity and rear caster wheels for 360 degrees of multi-planar movements and motor skill acquisition. The smart resistance ranges from 0-700 lbs depending on the level selected on the sled dial (three manual settings with ~225 lb increments) or via an optional app controlled from a smartphone. Aside from the linear mode, stabilizers may be engaged with a change-of-direction mode allowing for unique multi-planar resistive movements (also using three manual settings of ~225 lb increments).

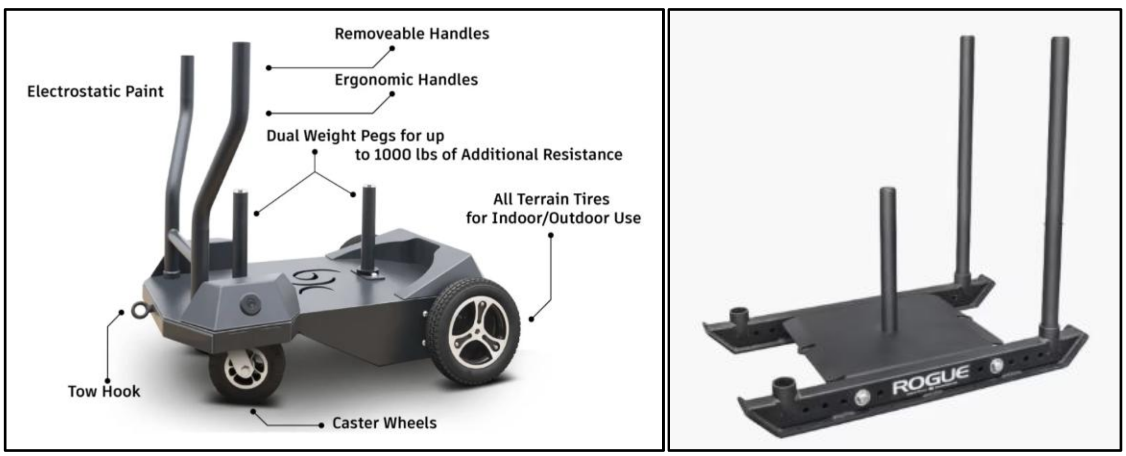

Figure 1. Motorized resistance sled (MRS) (left panel) and traditional resisted sled (CON) (right panel).

Testing procedures

All participants were tested at baseline and 8-week time points with identical protocols followed before each testing session. To ensure accuracy, reliability and consistency in test administration, all pre-and post-testing occurred in the same location and time of the day (i.e., early evening to optimize diurnal effect on performance) by the same investigator. All participants completed a familiarization session during which all testing protocols were practiced until participants were confident and utilizing proper form. The following testing sequence was used:

Anthropometric measures

Body mass and height: Body mass was measured on a calibrated medical scale (accuracy ± 0.1 kg), and height was determined using a precision stadiometer (Seca, Hanover, MD, United States; accuracy ± 0.01 m). In a fasted state and after voiding their bladder, participants were instructed to remove unnecessary clothing and accessories prior to being weighed, as well as remove their shoes prior to taking height measurements.

Body composition: Body fat percentage was measured using a validated (Dolezal et al., 2013) octopolar, multi-frequency, multi-segmental bioelectrical impedance analyser (InBody Co., Seoul, Korea Republic). To ensure accuracy, participants adhered to standard pre-measurement BIA guidelines recommended by the American Society of Exercise Physiologists (Heyward, 2001). The test was performed after at least 3 hours of fasting and voiding, with participants instructed to remain hydrated and to not exercise 2 hours before testing. After investigators explained the procedure, the participants stood upright with their feet on two metallic footpads while holding a handgrip with both hands. The instrument measured resistance and reactance using proprietary algorithms.

Performance measures
20 m sprint: The sprint test is widely used in sports and fitness to evaluate a person's linear acceleration and speed (Binnie et al., 2013). The testing session began with a standardized warm-up consisting of jogging (5 min), dynamic stretching (5 min), and a number of short sprints building up to maximum intensity (4 x sub-maximal and 2 x maximal). Following completion of the warm-up, participants completed 3 x 20 m sprints from a standing staggered stance with their non-dominant foot forward through the electronic timing gate system (Fusion Sports, SmartSpeed, Australia). Participants started 0.3 m behind the starting point and timing gates were positioned at 0, 5, 10, and 20 m. Participants were instructed to start when they were ready and to sprint through the 5 m past the final gate. The fastest time to each of the three distances out of all of the attempts was extracted for data analysis.

Abalakov jump: Using a previously validated electronic jump mat (Probotics, Inc., Huntsville, AL, United States) participants were instructed to stand on the mat with their feet at hip-width and perform a counter movement jump (CMJ) (Leard et al., 2007; Rodriguez-Rosell et al., 2017). Participants were allowed to prepare for the jump by bending their knees and loading their subsequent arm swing before performing a jump for maximal height. The jump height was computed using the computer interfaced with the jump mat. A total of three trials were conducted with rest intervals of 30 s between trials, with the average of the three trials recorded. Jump height was calculated based on "*hang time*." The following equation: Ht = t^2 * 1.227, where t is hang-time in seconds, and 1.227 is a constant derived from the acceleration of gravity (Harman et al., 1991), was used to calculate hang time, defined as the time from the feet leaving the mat to their return.

5-10-5 Pro agility test: This test is used to assess a person's change of direction (i.e., agility), speed, and leg strength. While this test is described in more detail by Moran et al. (2018), the key points are summarized. A distance of 10 m was measured and bisected with a cone, which represented the test's starting point. The timing of the test started when the participant began moving to their left or right. The participant was instructed to run 5 m in either direction and touch one of the end-line cones before immediately reversing their course to run 10 m to the opposite end. The participant would subsequently touch the opposite-ended cone and change direction one final time. The test was concluded after the participant sprinted the 5 m back through the initial starting position. One timekeeper, using a smartphone timer, was positioned at the start/finish cone to time the trial. A 3-minute recovery period was given between each of the three trials. The average of the three trials was recorded.

Statistical analysis

Descriptive statistics are presented as median and interquartile range (IQR). Data deviated significantly from normality per Shapiro-Wilk tests. Wilcoxon rank-sum tests were utilized and a Holm-Bonferroni correction applied. Effect sizes were measured by Cohen's d after undergoing transformation from η^2. Statistical significance was determined by $\alpha = 0.05$ and all tests were two-tailed. All data were exported to IBM SPSS Statistics for Windows, version 22 (IBM Corp., Armonk, N.Y., USA) for analysis.

RESULTS

Table 2. Anthropometric and performance characteristics between CON vs MRS before and after training.

Variables	CON				MRS				∆ Post-training (CON vs MRS)	IQR	*p*	*Cohen's d*
	Baseline		Post-training		Baseline		Post-training					
	Median	IQR	Median	IQR	Median	IQR	Median	IQR				
Age (yr)	21.0	2.0			21.5	2.0						
Height (cm)	179.0	12.7			179.0	8.3						
Body Mass (kg)	86.5	17.5	89.2	18.2	87.2	13.5	90.0	15.2	2.5	2.1	.741	
Body Fat (%)	16.5	7.2			16.2	6.8						
20m Sprint (sec)	3.1	0.1	3.0	0.1	3.1	0.1	3.0	0.1	-0.1*	0.1	<.001	*1.9*
5-10-5 Pro Agility Test (sec)	2.5	0.1	2.4	0.1	2.5	0.1	2.4	0.1	-0.1*	0.0	.005	*0.9*
Abalakov Jump Distance (cm)	75.0	6.0	80.4	5.3	74.8	5.3	82.6	3.5	6.0*	3.0	.003	*1.1*
Abalakov Jump Power (W)	*7062.3*	*1616.6*	*7649.4*	*1424.1*	*7087.6*	*834.3*	*7873.6*	*965.8*	*639.2**	*302.4*	*.002*	*1.0*

*Note. CON = Control Group (Traditional Resistance Sled); MRS = Motorized Resistance Sled Group; IQR = Interquartile Range; *p < .05.*

Two players had to withdraw from the investigation either due to injury or illness. No significant differences existed between CON and MRS for all baseline anthropometric and performance variables. Moreover, no significant differences were detected in body mass before and after undergoing the training protocols. Regarding changes in post-training between groups: 20-meter sprint times were significantly reduced in MRS relative to CON ($p < .001$; $d = 1.9$). Similarly, 5-10-5 Pro Agility Test times were lower in MRS compared to CON ($p < .005$; $d = 0.9$). Improvements in CMJ height and peak power were also significantly higher in MRS than CON (6.0 ± 3.0 cm, $p < .003$, $d = 1.1$; 639.2 ± 302.4 W, $p < .002$, $d = 1.0$, respectively).

DISCUSSION

The primary aim of the present study was to compare the effects of motorized resistance sled (MRS) training with traditional sled training (CON) on sprinting, power, and agility in collegiate football players. Improvements in performance across all assessments, including indices of lower body power, agility, and sprinting, were significantly greater in the MRS training group. These results are the first to demonstrate the efficacy of this novel resistance modality in improving key performance metrics and physical development in football players.

Given that the exercise regimen implemented in the present study incorporated multi-planar movements, there are few comparable studies available. Most existing research on resistance sled training has focused exclusively on the effects from either sled pushing or pulling. However, the improvements observed with sled training in this study can still be analysed in the context of each specific movement.

Sled pulling, pushing, and lateral movements

Sled pulling has yielded mixed results in improving various performance metrics. In a six-week study comparing the effects of sled training with a load of 12.6% body mass to resistance, plyometric, and traditional sprint-based training methods, there were no significant differences in improvements in 0-10 m sprint, reactive strength, and 3-RM squat performance between modalities (Lockie et al., 2012). Similarly, a six-week study of resisted sled training at 30% body mass compared to traditional sprint-based training in professional soccer players found no significant difference in improvements of Abalakov jump and sprint performance (McMorrow et al., 2019). Minimal improvements in sprint performance were also observed in collegiate lacrosse players after a seven-week training program comparing resistance sled training loaded at 10% body mass to traditional sprint training and weighted vest training at an 18.5% body mass load (Clark et al., 2010).

Conversely, sled pulling while utilizing a velocity decrement (Vdec) loading strategy has proven to be more effective. In a nine-week resisted sled training protocol with professional male soccer players, loads inducing 50 and 60% Vdec were compared to traditional training (Lahti et al., 2020). While both sled training groups yielded significant improvements in 10-30-m split times, only the 50% Vdec group demonstrated significantly greater gains in peak power and 0-10-m split times compared to the control group. The authors posited that since maximal power output has been shown to occur at approximately 50% of maximal velocity while sprinting, training adaptations that enhance force production at higher velocities may facilitate improvements in sprint performance. Given that the MRS group noted significant improvements in sprint time relative to CON, we posit that a similar increase in horizontal force production may have propagated these enhancements.

Similarly to sled pulling, sled pushing protocols have yielded conflicting results. In a five-week resisted sled training program with basketball players, significant improvements were observed only in horizontal jump performance among the sled-pushing group (Gottlieb et al., 2024). No significant improvements were found in sprinting and agility metrics, which the authors suggested might be due to bodyweight-based loading strategies and insufficient training duration. Another study, which utilized a six-week sled-push training protocol, found a significant difference in a 1-RM sled push of 9.1 meters in the low and high-volume training groups relative to the control (Bernard et al., 2021). Notably, no significant differences were detected in the Wingate power test, standing long jump, or vertical jump between the training and control groups. The authors similarly noted the duration of the training intervention as a potential factor affecting anaerobic training adaptations. The performance improvements observed across every outcome measure in MRS suggest that the eight-week training period was sufficient for training adaptations to occur.

Existing literature has highlighted cadence as a key limitation in sled-pushing protocols (Rosario 2020). Since the pace at which participants push the sled is typically self-selected, this may lead to inconsistent training responses (Bernard et al., 2021). Research indicates that faster sled-pushing speeds increase muscle recruitment, particularly the gluteal muscles (Rosario et al., 2022), which enhances strength while delaying fatigue onset (Rosario et al., 2022). However, at slower speeds, reduced intensity may result in insufficient muscle activation, potentially limiting gains in strength and lower body power. This variability in cadence may have limited the effects of the previously outlined training protocols. Conversely, the present study's use of a standardized maximum-intensity cadence may have contributed to improvements in sprint and agility outcomes by optimizing muscle recruitment.

To our knowledge, no previously investigated sled training protocols have incorporated lateral movements with sled pushing or pulling. However, incorporating both linear and multidirectional movements that involve change-of-direction speed is pivotal to performance sport (Bloomfield et al., 2007). Common training strategies to improve lateral movement speed include sport-specific drills, resisted movements in the horizontal plane, and plyometrics (Twist & Benicky, 1996). The findings of the present study suggest that laterally-resisted sled dragging may uniquely enhance an athlete's ability to execute rapid changes of direction, leading to improved performance in the 5-10-5 Pro Agility Drill.

Functional benefits

With the goal of leveraging improvements in strength, speed, and agility to enhance in-game performance, it is essential to consider the unique demands of American football. The fast-paced nature of the sport makes both linear and change of direction speed paramount across all positions (Hoffman, 2008; Pincivero & Bompa, 1997). However, the importance of these traits varies from position to position due to the distinct roles that players occupy (i.e.. offensive lineman tasked with blocking compared to defensive backs preventing receptions) (Robbins, 2011; Sanchez et al., 2023). These differing demands become especially important when examining the complementary matchups between positions on offense and defence. Interestingly, across all of the performance assessments used at the NFL combine, similar attributes have been observed between positions that directly compete against one another (i.e.. wide receivers versus cornerbacks or tight ends versus linebackers) (Robbins, 2011). Thus, the outcome of many plays could largely depend on which player possesses the more advantageous physical characteristics.

When comparing the attributes of collegiate football players, there is a clear distinction between athletes at different levels of competition. For instance, junior college football players have been shown to be slower than both Division I and II players in linear and change of direction speed (Lockie et al., 2016). Similarly, Division I starters consistently outperform their Division II counterparts in both performance and fitness measures (Garstecki et al., 2004). These differences suggest a strong association between athletic ability and the level of competition, wherein football players at higher levels demonstrate superior qualities. As such, improving strength, speed, and agility is of considerable interest to those aspiring to reach the most competitive levels of American football.

To enhance the characteristics essential to the sport, sled training, particularly with the novel MRS modality, should be considered as a viable tool. The sled push is widely regarded as an effective exercise for increasing an athlete's speed and horizontal force production (Cissik, 2011). Given the similarities in muscle fibre recruitment between sprinting and sled pushing (Bompa & Haff, 2017) sled training is well suited to improve sprinting performance. Key biomechanical elements of the sled push, such as lowered hips and positive shin angles, are also beneficial for enhancing the acceleration phase of the sprint (Haff & Triplett, 2015). This functional overlap allows sled pushing to simultaneously strengthen essential lower body musculature while promoting proper sprinting biomechanics.

The functional benefits of horizontally oriented exercises are tied to performing full hip extension, which is believed to enhance jumping, lateral movement speed, and sprint performance (Beardsley & Contreras, 2014). These movements specifically activate the gluteal and hamstring musculature, increasing horizontal strength and power output (Contreras et al., 2013). Moreover, increased hip extension velocity has also been associated with improved lateral acceleration and deceleration (Shimokochi et al., 2013; Brughelli et al., 2008). Additionally, given that hip extensors (i.e. gluteus maximus) compensate for reduced hamstring muscle function during fatigued states (Edouard et al., 2018), strengthening this musculature is crucial for preserving optimal in-game performance. Further research is needed to evaluate the efficacy of laterally-resisted sled movements to improve key performance metrics.

There are several limitations to the present study that should be considered before drawing practical implications. First, these findings are limited to a proprietary strength and conditioning off-season program inclusive of other exercises aside from the sled training performed. While groups were matched for identical regimens, the influence of the other exercises on performance measures are unknown and can't be discounted. Future research should include a third group that only performed the non-sled exercises. Second, while attempts were made to match identical starting loads relative to the athlete, the lack of standardization of training load performed thereafter was a confounder that could have explained the strength differences between groups. Lastly, the present study's findings are specific to younger, apparently healthy collegiate-aged football players and may not be generalized to other populations.

CONCLUSION

The present study is the first to investigate a multiplanar training protocol utilizing a novel motorized resistance sled. Improvements in all performance measures, including 20-meter sprint times, CMJ height and power, and the 5-10-5 Pro Agility Test, were observed in the MRS group relative to CON. These findings may be implemented into future training protocols for football players and other athletes across different sports seeking to improve speed, agility, lower body strength and power.

AUTHOR CONTRIBUTIONS

The study was conceived and designed by T.Y., P.G., and B.A.D. J.T., T.K.S., A.E.B., R.J.L., J.B., D.M.B., D.C., A.T., B.A.D., and T.H.N., performed data collection. T.Y., P.G., M.S.M., E.V.N. and B.A.D., completed data analysis. T.Y. and P.G., interpreted data and composed the manuscript while J.T., T.K.S., A.E.B., R.J.L., J.B., D.M.B., D.C., A.T., M.S.M., E.V.N., B.A.D., and T.H.N., made crucial edits. All authors have read and agreed to the published version of the manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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