International Journal of Sports Science 2022, 12(1): 14-22
DOI: 10.5923/j.sports.20221201.03

The Efficacy of Partial Range of Motion Deadlift Training: A Pilot Study

Brad Gillingham[1], Mark DeBeliso[2,*]

[1]Southwest Minnesota State University, Marshall, MN, USA
[2]Southern Utah University, Department of Kinesiology and Outdoor Recreation, Cedar City, UT, USA

Abstract The deadlift (DL) is a fundamental exercise that has a positive training effect on sprint speed, vertical jump performance and rate of force development. The DL is included in resistance training (RT) programs designed for sports that require enhancement of these performance measures. Additionally, maximum effort during full range of motion (FROM) or partial range of motion (PROM) DL are performed by strength athletes in competitions of maximum strength. Purpose: The study examined the effects of free weight DL PROM RT on maximum FROM and PROM DL strength. Methods: NCAA Division 2 male wrestlers were separated into two groups (F and FP) via a randomized matched pair design based on 1-RM FROM DL pre-intervention assessments. Pre-intervention testing also included the collection of a 1-RM PROM DL performed off the safety arms in a power rack with the bar height set at ≈ 2.54 cm above the patella. Both experimental groups employed a 6-week periodized RT intervention that included DL 1 day/week. The F group (n=9, age: 21.0±1.2 yr, height: 175.0±4.5 cm, mass: 75.2±10.6 kg) RT included 2 FROM DL sets. The FP group (n=9, age: 20.0±1.1 yr, height: 177.0±5.9 cms, mass: 82.6±9.9 kg) RT included 1 FROM DL set at the same prescribed intensity as the F group followed by 3 PROM DL sets, using supramaximal intensity ranging from 105-120% of 1-RM FROM DL depending on the week of the RT intervention period. Following the RT intervention, 1-RM PROM and FROM DL were re-assessed. Dependent t-tests were used to compare the 1-RM FROM and 1-RM PROM DL scores from pre to post RT intervention within experimental groups. Likewise, independent t-tests were used to compare dependent variable gain scores between groups ($\alpha<0.05$). Results: The FP group significantly improved 1-RM PROM DL ($p<0.05$). Additionally the FP group recorded a statistically significant 1-RM PROM DL gain score compared to the F group ($p<0.05$). Neither group significantly improved the 1-RM FROM DL ($p>0.05$). Conclusion: Both FROM and PROM RT programs maintained muscular strength in the FROM DL during an off-season NCAA Division 2 wrestling RT program that overlapped with in-season training. The findings also suggest that combining PROM with FROM DL RT can increase PROM DL strength.

Keywords Exercise, Resistance training, Performance, Supramaximal strength

1. Introduction

Resistance training (RT) is conducted by athletes to improve performance in speed, power, strength, endurance, muscle hypertrophy, and for injury prevention and rehabilitation [2,12,27]. The deadlift (DL) is a fundamental exercise that has a positive training effect on sprint speed, vertical jump performance and rate of force development (RFD) [10], and should be included in RT programs designed for sports that require enhancement of these performance measures [10]. Additionally, 1-RM DL are performed by strength athletes in competitions of maximum strength. It is the third discipline included in powerlifting competitions along with the back squat and bench press [38]. Full range of motion (FROM) or partial range of motion (PROM) DL are common events that are included in strongman and competitions [39].

Athletes are constantly trying to find new methods to push through plateaus and strengthen the range of motion (ROM) in and around sticking points [18]. PROM RT is a supramaximal method utilized by athletes to achieve maximum strength performance gains [3,9,12,20,21,29,40, 41].

The American College of Sports Medicine (ACSM) identifies key RT variables that need to be taken into consideration when developing a RT program. These RT variables include: (a) exercise selection and order; (b) intensity; (c) repetitions; (d) repetition speed; (e) volume; (f) rest intervals; and (g) frequency. The alteration of these RT variables is necessary to support progression in strength and performance [27]. A search of peer reviewed literature did not provide any research comparing DL RT intervention efficacies of PROM compared to FROM, or identification of

* Corresponding author:
markdebeliso@suu.edu (Mark DeBeliso)
Received: Jan. 17, 2022; Accepted: Feb. 25, 2022; Published: Mar. 15, 2022
Published online at http://journal.sapub.org/sports

PROM DL RT variables. However, scholarly work discusses the potential benefits of PROM as a RT method to increase maximum DL strength [4,16,20,40]. Moreover, information is available in strength RT publications that suggests PROM RT is a viable RT method to increase maximum DL strength [13,17,35,36,37].

Historically, world class strength athletes have incorporated PROM RT to increase DL strength. In 1949, Bob Peoples DL 725 lbs weighing 181 lbs. His RT methods included FROM, supramaximal PROM, heavy negatives, and isometric holds. His PROM RT was performed out of a power rack that he built with 4x4 wooden beams. Bolts were inserted into holes in the beams which allowed him to pull from three positions: (a) just below the knee; (b) mid-knee; and (c) just above the knee [17]. Strength legend Bob Peoples would also RT with progressive range of motion RT (PMT). He would dig a hole under the barbell, and start his RT a few inches below lockout. Over the duration of his RT cycle, he would fill the hole in with dirt until he was performing a FROM lift [36]. Whereas, in 1969 Don Cundy, four-time AAU Senior National powerlifting champion, became the first person in history to DL 800 lbs. Cundy performed RT using a combination of FROM and supramaximal PROM from two inches below the knee out of a power rack [37]. Furthermore, International Powerlifting Federation (IPF) Hall of Fame powerlifters Don Reinhoudt and Brad Gillingham included supramaximal PROM DL into their RT programs. Both of these athletes are former IPF world record holders in the DL event, and have set world records in PROM maximal DL events in strongman competitions. Reinhoudt would pull 6-7 progressive singles out of a power rack following his FROM workout from “the knees up”, increasing the load 50-60 lbs each set [35]. Whereas, Gillingham RT with multiple supramaximal singles out of a power rack, utilizing pin positions ranging from 2.54 cm above the knee to several positions below the knee. The frequency of his PROM RT was every other week in place of his regular FROM workout [13]. During the 1960’s and 1970’s, Gillingham’s father, Green Bay Packer Hall of Famer, Gale Gillingham was an early pioneer in strength RT in the NFL. In the off-season he RT with supramaximal PROM singles in the squat, bench press, and DL out of a self-designed power rack [33].

PROM RT is a method of RT that restricts joint-angle ROM as opposed to FROM RT [3,9,14,15,19,26,29,41]. PROM RT is accomplished through isotonic, isokinetic, and isometric RT methods. The manipulation of ROM is a RT variable that can be manipulated similarly as duration, frequency, volume, rest intervals, and intensity to achieve desired RT adaptations [41]. Additionally, PROM RT can be incorporated using different methods to meet individual RT goals. Studies have been performed on high school, collegiate, high-level amateur athletes, and sedentary subjects [3,9,14,15,19,29,41]. Moreover, PROM RT has been utilized both in clinical rehabilitation settings, and as a RT method for athletes to develop maximum strength and power [3,9,14,15,19,29,41]. A study was conducted to determine the efficacy in developing knee extensor isometric strength in healthy sedentary subjects [14]. The results suggested that PROM RT may be applicable for individuals that are rehabbing knee injuries. Additionally, the effect of PROM RT was studied in healthy sedentary subjects for the development of isometric lumbar extension strength [15]. The results suggested that limited ROM RT could be useful in clinical rehabilitation for patients suffering from lower back pain with limited lumbar ROM. Multi-joint upper body RT was studied by Clark [9], and Massey [19] to determine if free weight PROM RT would benefit 1-RM bench press strength. Both of the studies investigated the effects of PROM RT in the deceleration zone. The bench press deceleration zone occurs at a vertical point of ascent near lockout [11]. According to Clark [9], PROM RT increased isokinetic peak force in the deceleration zone, as well as FROM bench throw displacement, and ½ ROM bench throws peak force. The findings suggest that strength and ballistic acceleration in the deceleration phase of the bench press may be improved by PROM RT. Massey [19] also found PROM RT, and the combination of PROM RT and FROM RT, to be equally productive as FROM RT in increasing maximum bench press strength. Several studies have examined the inclusion of PROM RT into squat RT to develop lower body strength, power, and speed. Bazler [3] conducted a study on 18 experienced lifters with a minimum 1-RM back squat ≥ 1.3 times bodyweight. One group RT with FROM, and the other group RT with a combination of PROM and FROM. The findings indicated that the combination group had greater strength gains in both the full squat and partial squat. Rhea [29] studied the effect of supramaximal PROM squat RT with ½ PROM and ¼ PROM compared to FROM squat RT on 28 college athletes to determine the effect of PROM RT on power production, vertical jump, and sprint speed. The athletes were divided into three groups that RT squats as part of a 12-week off-season RT program. The ¼ PROM group had the greatest improvement in the vertical jump and 40-yard sprint speed. Additionally, Whaley [41] studied the effect of squat progressive movement RT (PMT) on strength, power output, and vertical jump. PMT is a method that utilizes a consistent supramaximal load but increases ROM throughout the RT cycle. This study was completed on 36 high school athletes. The findings suggest that PMT RT provides equal increases in strength, but superior increases in vertical jump and power output compared to FROM RT.

Several studies have been completed to identify sticking points in the squat, bench and DL [11,16,18,21,22,42]. The sticking point refers to a region in the upward ROM of the lift when the vertical bar velocity begins to slow down or stop. The ability to complete a lift becomes more difficult at the sticking point [18]. If the bar velocity does not recover sufficiently following the sticking point it may result in a failed lift [11,22]. Therefore the sticking point can be the limiting factor in the completion of a maximal lift. Strengthening the range of motion (ROM) in and around sticking points may be beneficial to increase 1-RM.

According to Kompf [18], a sticking point is a result of underlying physiological and biomechanical mechanisms that are both exercise specific and athlete specific. Whereas, Zatsiorsky [40] suggests that maximal muscle strength changes throughout the ROM of an exercise as a result of changes in muscle lever arms and muscle force production. A kinematic analysis of the squat was performed at the 1974 A.A.U. Senior National Powerlifting Championship [22]. Several of the subjects were highly ranked international powerlifters. The sticking point was identified in the mid-ascent position during the concentric phase of the lift. All failed squat attempts stopped near the sticking point. Whereas, during the completion of the successful squat attempts the bar velocity increased after the sticking point. The sticking point in the squat is further defined in a study by Hales [16] to occur at an absolute thigh angle of 32° relative to the ground. A biomechanical analysis of the sticking point in the bench press was conducted on 10 elite male Australian bench pressers [11]. The results indicated that the ascent phase of the bench press, completed at 100% maximum load, can be broken down into four phases: (a) acceleration phase: (b) sticking region: (c) maximum strength region; and (d) deceleration phase. During the completion of the successful bench press attempts at 100% maximum load the bar velocity increased after the sticking point in the maximum strength region. Whereas, eighty percent of the failed lifts at 104% maximum load occurred in the deceleration phase. The diminished velocity that resulted from the minimum bar acceleration at the sticking point resulted in a failed lift. This is similar to findings by McLaughlin [22] in failed squat attempts. A kinematic analysis of the DL using experienced powerlifters was conducted by Hales [16] at a United States Powerlifting Federation (USPF) national qualifier. The study identified three distinct stages during the execution of DL: (a) lift-off (LO); (b) knee passing (KP); and (c) lift completion (LC). The sticking point was identified in the KP stage in a region that is approximately 6 cm distal to the patella at an observed thigh angle approximately 60° in relation to the ground. The findings suggested that an increase in bar velocity was identified after the sticking point. However, a study by McGuigan [21] using experienced powerlifters in New Zealand, indicated that once the vertical bar velocity decreased in the DL, the velocity continued to decrease until the completion of the lift.

Supramaximal PROM RT may be an effective method to increase maximum strength by strengthening a targeted ROM in and around sticking points [3,9,12,18,19,29,40,41]. Supramaximal RT is a method of RT with a load that is heavier than the maximum load that can be lifted in a FROM movement. According to Suchomel [34], the development of muscular strength is dependent on a combination of morphological and neural factors. Morphological factors include: (a) muscle cross-sectional area; (b) muscular architecture; and (c) musculotendinous stiffness. Whereas, neural factors include: (a) motor unit recruitment; (b) rate coding; (c) motor unit synchronization; and (d) neuromuscular inhibition. Verkhoshanky [40] indicates that supramaximal methods can be utilized to acquire RT-induced central nervous system and neuromuscular adaptations. Whereas, McGuigan [20] suggests that supramaximal loads reduce neural inhibition, and potentiate neuromuscular adaptation. However, a meta-analysis conducted by Schoenfeld [31] determined that PROM RT is not an effective method to increase muscle cross-sectional area.

Supramaximal DL RT can be implemented using several different PROM methods including block pulls, oversized plates, power rack DL off of the pins, and by using strongman event implements. The block DL or block pull uses wooden or rubber blocks placed on the ground. The plates rest on the blocks and the lift is completed in an elevated position. The ROM of the lift is determined by the height of the blocks. Oversized plates such as wagon wheels are constructed of steel or are available in rubber bumper plates. The wagon wheel is 66.04 cm in diameter and places the bar in a ROM 10.16 cm higher than a standard DL. Standard sized plates are loaded on the outside of the wheels to increase the load. Power rack DL off of the pins are completed in a power rack with the pins sets at different levels to control ROM. The power rack may provide the lifter with the most versatility in adjusting ROM as the pins can be inserted into different settings in the rack [13,17,33,35,37]. In addition, strongman contests often include a PROM DL event using large tires, spheres, or various riggings attached to the bar.

Given the aforementioned potential for PROM RT (as a RT modality) to improve strength at a specific ROM, it is of interest to strength athletes and coaches to have the results of controlled research made available in this regard. As such the purpose of this study was to determine the effects of free weight DL PROM RT on 1-RM FROM and PROM DL strength. It was hypothesised that inclusion of the PROM DL as a RT exercise modality would lead to greater increases in 1-RM FROM and PROM DL strength then FROM DL RT alone.

2. Methods

2.1. Participants

Twenty-two NCAA Division II male athletes on the Southwest Minnesota State University wrestling team with at least one year of RT experience in the SMSU strength and conditioning program participated in this study. The participants were athletes ranged in age from 19-23. Individuals with injuries that had the potential to affect DL performance were excluded from the study as well as athletes who did not perform a DL ≥ 315 lbs. (143.2 kgs). Permission to conduct this study was obtained through an University Institutional Review Board (#27-032021b). A written informed consent was obtained from the participants prior to the study initiation. Informed consent was also provided by participants for the use of their unmasked photos for the purpose of scholarly presentation.

2.2. Instruments and Apparatus

All pre and post-intervention testing and all RT sessions were conducted at the Southwest Minnesota State University strength training facility. The equipment included Rogue calibrated bumper plates, free weights, Dynamic Fitness & Strength 20.4 kg men's weightlifting bars, chalk, collars, lifting belts, lifting straps, and a heavy-duty power rack with 2-inch hole spacing (5.08 cm). The maximum completed FROM and PROM DL were recorded on a chart in lbs next to the lifters name by strength coaching staff.

2.3. Procedures for Assessments

Figure 1. Participant performing the FROM DL with starting position in the left pane and the finishing position in the right pane

Figure 2. Participant performing the PROM DL with starting position in the left pane and finishing position in the right pane

Figure 3. A 2.54 cm block was used to determine that bar height above the patella ≈2.54 cm

The study was performed during the fall preseason wrestling strength and conditioning RT cycle at SMSU. All healthy members of the team were required to test for 1-RM strength in the clean, squat, bench, and DL at the beginning of the fall semester to determine preseason RT program intensity based on 1-RM. Pre-intervention testing was conducted at that time to determine 1-RM FROM (Figure 1) and 1-RM PROM (Figure 2) DL. Inclusion testing to determine ≥ 143.2 kg FROM DL occurred simultaneously to determine qualified participants. The height, weight, and age of the participants were recorded at that time. A 10-minute general warm-up including the band pull-apart, Spiderman stretch, walking lunge, box jump, overhead squat and kettle bell swing proceeded 1-RM testing. Lifting was observed by experienced coaching staff to determine correct execution of the lift. Strength testing was performed in accordance with performance guidelines of the National Strength and Conditioning Association [2]. All athletes were given three attempts to determine 1-RM FROM DL after a progressive warm-up. DL's were completed to full lockout with no downward movement of the bar, no ramping the bar up against the legs, and no excessive rounding of the back. Participants were instructed to put the bar down when performance standards were not being met. After a 5-minute break, qualified participants were instructed to perform a 1-RM PROM DL in a power rack with the bar set on the pins at ≈ 1 inch (2.54 cm) above the patella. A 2.54 cm block was used to determine that bar height above the patella was ≈ 2.54 cm above the patella (Figure 3). One-half inch (1.27 cm) hard rubber mats were used when necessary to adjust the bar height. The participants were given an opportunity to warm-up to a weight equal to their 1-RM FROM DL. Three attempts were given to determine 1-RM PROM DL. Lifting straps were worn by all participants to ensure test consistency.

Post-intervention 1-RM FROM, and 1-RM PROM DL testing was conducted the week following the 6-week RT intervention, with a minimum of 72 hours rest. Retest procedures were identical to pre-intervention testing. The resultant data was collected to be analyzed. Data from individuals who missed more than two RT sessions were excluded from further analysis.

2.4. Procedures for RT Intervention

The participants were randomly assigned using a matched pair random assignment procedure. When the participants' FROM and PROM 1-RM were established the FROM 1-RM scores were rank ordered from highest to lowest. The two highest scores were selected, and randomly assigned to either a traditional FROM DL RT group (F), or to a combination of FROM and PROM DL RT group (FP). This process was continued until two ≈ equal groups were formed based on the FROM 1-RM DL scores, which was verified by the results of a two-tailed t-test (p=0.85). The participants from both groups participated in a three day/week periodized upper and lower body preseason wrestling RT program, and fall wrestling conditioning. Participants were instructed to not undertake any new exercise habits or activities that could otherwise affect the experiment. The 6-week RT intervention was performed by both groups along with other non-participant team members starting the next week following the testing day.

Both groups DL RT on Mondays in addition to a periodized program of power cleans, ballistic squats, assistance exercises, and functional strength RT. Wednesday's RT included periodized upper body RT including heavy bench press, assistance exercises, and functional strength RT for both groups. Whereas, Friday RT included periodized lower body/upper body RT including hang cleans, back squats, ballistic bench, assistance exercises, and functional strength RT for both groups. The F group DL RT included 2 sets of 3-5 repetitions FROM DL at a prescribed periodized intensity (Table 2). The FP group DL RT included 1 set of 3-5 repetitions FROM DL at the same prescribed intensity as the F group. The FP group also included 3 sets of a single PROM DL repetition after completion of two progressive warm-up single lifts with ≤ 100% FROM 1-RM (Table 2).

Week one PROM RT intensity started off with 100% FROM 1-RM. When 3 sets of a single repetition were performed with the target weight the intensity was raised to 105% the following week. Likewise, when 3 sets of a single repetition were performed at 105% the intensity was raised to 110% the following week. Intensity continued to be increased 5% each week throughout the intervention following the same procedure. When a participant failed to complete a lift, the weight was reduced to 100% FROM 1-RM for the remaining attempts during that session. By including two progressive PROM warm-up singles with ≤ 100% FROM 1-RM in addition to the programmed 3 sets of a single PROM repetition it ensured that each group performed approximately the same workload each week. Repetitions were performed in a power rack with 3.08 cm (2-inch) increments. The pin heights were set ≈ 2.54 cm above the patella. Hard rubber mats (1.27 cm) were used when necessary to adjust the pin height to ≈ 2.54 cm above the patella. The bar was lifted directly off of the pins. The subjects were given an individualized workout each day with their prescribed RT loads. They recorded their compliance with the RT outline, including items such as missed repetitions, skipped sets, or missed workouts. The conservative increases in FROM and PROM loading minimized the occurrence of missed repetitions. Additionally, lifting straps were worn by all participants.

2.5. Reliability

In order to maximize the validity of the 1-RM FROM and PROM DL assessments: all athletes used the same high quality calibrated equipment; and followed the testing protocol based on the National Strength and Conditioning Association (NSCA) 1-RM testing protocol [2]. A study by Bishop [5] determined that actual 1-RM testing is more accurate in determining maximum DL strength when compared to multiple repetition testing procedures that utilize percentage prediction charts. Previously, a high intraclass correlation coefficient (ICC > 0.91) was found for the reliability of standardized 1-RM testing protocols to assess muscle strength regardless of muscle group size, location or gender [32].

2.6. Design and Analysis

The 1-RM FROM and PROM DL were compared pre and post-intervention with paired t-tests. A common gain score was also calculated for the dependent variables of 1-RM FROM DL and 1-RM PROM DL. Gain scores were compared between experimental groups (F and FP) for each dependent variable with independent t-tests. Statistical significance was $\alpha \leq 0.05$. Effect size (ES) was also calculated and reported as suggested by Rhea [24]. Statistical calculations were conducted with Microsoft Excel 2013.

Table 1. Participant's progression protocol for assessing FROM and PROM 1-RM DL

Repetitions	Load
5-10	≈33% 1-RM
3-5	≈65% 1-RM
3-5	≈75% 1-RM
1	≈80% 1-RM
1	≈85-90% 1-RM
1	>90%
1, 1, 1	Until failure/find max

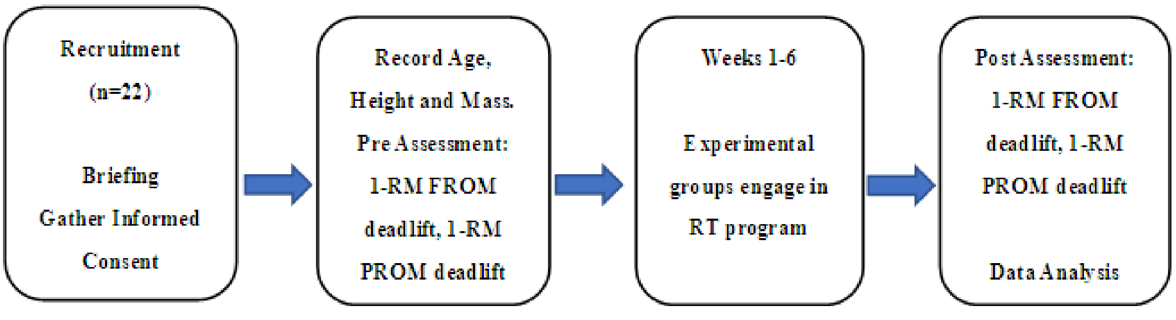

Figure 4. Study timeline (FROM-full range of motion; PROM-partial range of motion)

Table 2. Experimental RT programs the participants followed for 6-week protocol

Week	F Group	FP Group**
1	2x5 @ 75% 1-RM	1x5 FROM-3x1 PROM@100%
2	2x5 @ 80% 1-RM	1x5 FROM-3x1 PROM @100-105%*
3	2x3 @ 85% 1-RM	1x3 FROM-3x1 PROM@100-110%*
4	2x5 @ 80% 1-RM	1x5 FROM-3x1 PROM@100-110%*
5	2x5@ 85% 1-RM	1x5 FROM-3x1 PROM@100-115%*
6	2x3 @ 90% 1-RM	1x3 FROM-3x1 PROM@100-120%*

* 5% 1-RM was added, if all 3 single PROM repetitions were successfully lifted the proceeding week.
** Note: the FP group employed an identical percentage to the F group FROM each week.

3. Results

A total of 22 participants originally engaged in the study with one participant dropping out of the study due to health reasons prior to pre-invention RT. The F group consisted of 11 participants and the FP group consisted of 11 participants. One participant on the F group dropped out of the study when he left the team, and one participant dropped out of the study due to health reasons unrelated to the study. Two participants in the FP group dropped out of the study due to health reasons unrelated to the study. This left 18 participants completing the study with both of the experimental groups consisting of 9 participants. No participants missed more than two RT sessions, and there were no injuries experienced by the participants as a result of engaging in the RT sessions, or dependent variable assessments.

Table 3 presents the participant descriptive information. Tables 4 and 5 provide the mean and standard deviation results for the participant's 1-RM FROM and 1-RM PROM DL pre and post RT intervention.

Table 3. Participant Descriptive Information

	Age (years)	Height (cm)	Body Mass (kg)
F n=9	21.0±1.2	175.0±4.5	75.2 ±10.6
FP n=9	20.6±1.1	177.0±5.9	82.6 ±9.9

Mean ± standard deviation.

Table 4. Full Range DL 1-RM

	1-RM DL (kg)			
	Pre	Post	Gain	ES
F n=9	189.9±32.8	184.6±27.9	-5.3±13.4	-0.16
FP n=9	193.4±43.2	198.0±36.7	4.5±12.2	0.11

Mean ± standard deviation. ES-effect size in standard deviations kg.

Neither experimental group improved the 1-RM FROM DL pre to post RT intervention (p>0.05). Likewise there was not a significant difference in gain scores of the 1-RM FROM DL between the experimental groups (p>0.05). The F experimental group did not improve the 1-RM PROM DL pre to post RT intervention (p>0.05). However, the FP experimental group improved the 1-RM PROM DL pre to post RT intervention (p>0.05). Additionally the FP group recorded a significantly greater 1-RM PROM DL gain score compared to the F group (p<0.05).

Table 5. Partial Range DL 1-RM

	1-RM Partial Range DL (kg)			
	Pre	Post	Gain	ES
F n=9	221.7±40.1	233.3±38.3	11.6±23.2	0.29
FP n=9	230.3±43.0	275.5±41.5*	45.2±18.9**	1.05

*Significant improvement pre-post intervention (p<0.05). **Significant difference between gain scores (p<0.05). Mean ± standard deviation. ES-effect size in standard deviations.

4. Discussion

The purpose of this study was to determine the effects of free weight DL PROM RT on maximum FROM and PROM DL strength. The independent variable was free weight DL RT utilizing a combination of FROM and PROM modalities. The two dependent variables (DV) were 1-RM FROM DL and 1-RM PROM DL. It was hypothesized that the experimental group using both the FROM and PROM DL modalities would demonstrate superior gains in the DVs when compared to the experimental group using the FROM DL modality alone.

The results of the study were mixed. The hypothesis was supported by the PROM 1-RM DV (p<0.05) statistically improving as a result of the FP RT intervention. Likewise, the FP group demonstrated a statistically greater improvement in 1-RM PROM gain scores compared to the F group (p<0.05). Whereas, the hypothesis was not supported with the 1-RM FROM DV. Neither group significantly improved the 1-RM FROM DL as a result of the RT interventions (p>0.05). The counterintuitive lack of improvement of the 1-RM FROM DL is addressed in the limitations described below.

The manipulation of ROM is a RT variable that can be manipulated similarly as duration, frequency, volume, rest intervals, and intensity to achieve desired RT adaptations [41]. This study employed supramaximal PROM RT above the sticking point. There are varied opinions regarding the most advantageous biomechanical position to incorporate PROM RT. According to Arandjelovic [1], the most effective method for strengthening the sticking point is to increase strength at a different point in the lift due to the changes in neuromuscular and biomechanical force production. Bazyler [3] suggests that terminal ROM is more optimally loaded with PROM than with FROM. This strategy was supported by a biomechanical analysis of the DL completed by McGuigan [21] that indicated that PROM RT should be conducted above the sticking point. Additionally, McGuigan [20] indicating that PROM RT can be utilized to overload the area of maximal strength with supramaximal loading above the sticking point. However, Hales [16] suggests that the bar should be positioned at the beginning of the sticking point at a location 6 cm below the patella to target the entire sticking point region. This research was supported by Beckham [4] that determined isometric forces were the lowest in the lockout position of the DL, and that RT should concentrate on the lower ranges of motion to increase 1-RM. Whereas, Beeler [5] contradicted the benefits of PROM RT suggesting that the body mechanics used in the PROM DL are different than the body mechanics used in the FROM DL. The results of the current study reinforce the need for future research to determine the most effective biomechanical PROM position to RT the DL with supramaximal loads in relation to the sticking point.

Another consideration for future research would be to determine the effect of DL PROM RT on the vertical jump and speed performance measures. Two of the main compound exercises to build hip extension strength are the DL and the squat. The hip extensors provide the torque necessary to accelerate the body upward and forward from the hip flexion position [24]. A study using male participants with at least 3 years of RT experience compared the RT effects of the DL and squat on lower body strength and vertical jump power. The results indicated that squat or DL RT could result in similar improvements in lower body strength and vertical jump performance [25]. Research has been conducted to determine the effect of PROM squat RT on vertical jump and speed. Rhea [29] studied the effect of ½ PROM and ¼ PROM compared to FROM squat RT on power production, vertical jump, and sprint speed on 28 college athletes. The ¼ PROM group had the greatest improvement in the vertical jump and 40-yard sprint speed. Additionally, Whaley [41] conducted a study on 36 high school athletes to determine the effect of squat progressive movement training (PMT) on strength, power output, and vertical jump. PMT is a method that utilizes a consistent supramaximal load but increases PROM throughout the RT cycle. The findings of the study suggest that PMT RT provides equal increases in strength, but superior increases in vertical jump and power output compared to FROM RT. Future studies should be performed to determine if DL PROM RT has the same positive training effect on vertical jump and speed performance measures as squat PROM RT.

There are a few limitations to this study. The first limitation was that the fall off-season RT cycle overlapped 3-weeks with in-season training. NCAA collegiate wrestlers have two off-season training cycles during the school year. The NCAA limits student athletes to 8-hours per week participation in RT, conditioning and/or team activities during the off-season. The focus of these contact hours during the first 5-weeks of the study was concentrated on RT. However, the NCAA allows the contact hours to be expanded to 20-hours per week during the playing season [23]. The participants started intensive sport specific wrestling practice during the last 2-weeks of the RT cycle and during the week of post-intervention testing. At this point the participants were not able to concentrate entirely on RT. Additionally, the participants were cutting down to in-season body weight which included a more intensified focus on calorie restricted diets. The second limitation was that the duration of the study was limited to 6-weeks. Most RT programs designed for strength development are 12-16 weeks in length. For example the NSCA provides a 12-week RT program in the NSCA Basics of Strength and Conditioning Manual [30]. The current study lasted 6–weeks and led to a 2.3% increase in the FROM DL among the FP participants, not considered significant. However, if the study duration had been a more typical 12-week duration RT program it could be projected to a 4.6% strength increase. World class strength athletes employ PROM RT as part of their annual macrocycle that is repeated year after year [13,17,33,35,37]. If a 12-week RT program was to be repeated several times throughout the training year the increase in 1-RM could potentially be projected to an even larger gain score. Future studies should lengthen the RT intervention period to 12-weeks. If wrestlers are chosen as a future participant group a better time to conduct the study would be during the spring semester off-season training period after the wrestling season is over.

Finally, the current study compared FROM as the DL modality as compared to a combination of FROM and PROM as the DL modality. Future research should also explore comparing FROM with PROM (only) as the DL modalities.

One of the challenges that was faced when developing this study was to find a participant group consisting of well-trained athletes to participate in a study that involved an advanced RT technique. Minimum participant inclusion requirements were one year of experience in a collegiate RT program, and a 1-RM DL ≥315 lbs. (143.2 kgs). These requirements ensured that participants were healthy, well trained and were knowledgeable about the expectation of effort that was expected during the RT intervention. A limited number of RT programs utilize 1-RM DL RT intensity. Potential participant groups are restricted to sports that require the development of absolute strength in the upper and lower body. Wrestling is a sport that requires both upper body, and lower body strength, power, and endurance [8]. Furthermore, the DL and variations of the DL have sport-specific applications to the sport of wrestling [6]. Other potential participant groups could include powerlifters, strongman, CrossFit, and football athletes.

5. Practical Applications

Practical applications based on this study include the use of the RT program employed in the study by collegiate athletes who are well experienced in RT, or other experienced RT athletes that are looking to improve performance in 1-RM PROM DL strength. Evidence based significant findings suggest that RT athletes that are looking to improve 1-RM in the PROM DL should be employing PROM RT into their RT protocol. Furthermore, terminal ROM is more optimally loaded with PROM than with FROM when trained above the sticking point.

Although no statistically significant result was obtained from the combination of FROM and PROM RT, the results suggest that RT with a combination of FROM and PROM may be beneficial to increase performance in the 1-RM FROM DL as was noted by the 2.3% increase among the FP participants. Additionally, DL RT that includes a combination of FROM and PROM may be more effective than FROM RT to maintain or improve DL strength during an off-season RT program that overlaps with in-season training. Finally, the results suggest that PROM RT may be a feasible RT modality to include during an in-season RT program to maintain strength. This finding provides athletes and coaches with evidence based options with respect to RT protocol design.

REFERENCES

[1] Arandjelović, O. (2011). Optimal effort investment for overcoming the weakest point: New insights from a computational model of neuromuscular adaptation. *European Journal of Applied Physiology, 111*(8), 1715-1723.

[2] Baechle, T.R. & Earle, R.W. (2008). *Essentials of Strength and Conditioning* (3rd Edition). Champaign IL: Human Kinetics.

[3] Bazler, C. D., Sato, K., Wassinger, C. A., Lamont, H. S., & Stone, M. H. (2014). The efficacy of incorporating partial squats in maximal strength training. *Journal of Strength and Conditioning Research, 28*(11), 3024-3032.

[4] Beckham, G. K., Lamont, H. S., Sato, K., Ramsey, M. W., Haff, G. G., & Stone, M. H. (2012). Isometric strength of powerlifters in key positions of the conventional deadlift. *Journal of Trainology, 1*, 32-35.

[5] Beeler, M. K., Inglis, S. D., Ammon, R., Kraemer, W. J., & Comstock, B. A. (2017). Kinematic and kinetic analysis of the partial and conventional deadlift in resistance-trained males [Abstract]. *Medicine & Science in Sports & Exercise, 49*(5S), 390. doi: 10.1249/01.mss.0000517947.32476.9e.

[6] Bird, S., & Barrington-Higgs, B. (2010). Exploring the deadlift, *Strength and Conditioning Journal*, *32*(2) 46-51.

[7] Bishop, A., DeBeliso, M., Sevene, T. G., & Adams, K. J. (2014). Comparing one repetition maximum and three repetition maximum between conventional and eccentrically loaded deadlifts. *Journal of Strength and Conditioning Research, 28*(7), 1820-1825.

[8] Chaabene, H., Negra, Y., Bouguezzi, R., Mkaouer, B., Franchini, E., Julio, U., & Hachana, Y. (2017). Physical and physiological attributes of wrestlers: An update, *Journal of Strength and Conditioning Research, 31*(5), 1411-1442.

[9] Clark, R. A., Humphries, B., Hohmann, E., & Bryant, A. L. (2011). The Influence of variable range of motion training on neuromuscular performance and control of external loads. *Journal of Strength and Conditioning Research*, *25*(3), 704-711.

[10] Del Vecchio, L., Daewoud, H., Green, S. (2018). The health and performance benefits of the squat, deadlift, and bench press. *MOJ Yoga & Physical Therapy*, *3*(2), 40-47. https://10.15406/mojypt.2018.03.00042.

[11] Elliott, B.C., Wilson, G.J., & Kerr, G.K. (1989). A biomechanical analysis of the sticking region in the bench press. *Medicine & Science in Sports & Exercise, 21*(4). doi: 10.1249/00005768-198908000-00018.

[12] Fleck, S. J., & Kraemer, W. J. (2014). *Designing Resistance Training Programs* (4th ed.). Champaign, IL: Human Kinetics.

[13] Gillingham, B. (2011). *The Deadlift-Building Hip, Back, and Leg Strength*. Marshall, MN.

[14] Graves, J. E., Pollock, M. L., Jones, A. E., Colvin, A. B., & Leggett, S. H. (1989). Specificity of limited range of motion variable resistance training. *Medicine and Science in Sports and Exercise*, *21*(1), 84-89.

[15] Graves, J. E., Pollock, M. L., Leggett, S. H., Carpenter, D. M., Fix, C. K., & Fulton, M. N. (1992). Limited range-of-motion lumbar extension strength training. *Medicine and Science in Sports and Exercise, 24*(1), 128-133.

[16] Hales, M. E., Johnson, B. F., & Johnson, J. T. (2009). Kinematic analysis of the powerlifting style squat and the conventional deadlift during competition: Is there a cross-over effect between lifts? *Journal of Strength and Conditioning Research, 23*(9), 2574-2580. doi:10.1519/JSC.0b013e3181bc1d2a.

[17] Hise, B. (1964). Bob Peoples – deadlifter. http:/ditillo2.blogspot.com/2008/02/bob-peoples-deadlifter.html.

[18] Kompf, J., & Arandjelović, O. (2016). Understanding and Overcoming the Sticking Point in Resistance Exercise. *Sports Medicine (Auckland, N.Z.), 46*(6), 751–762. https://doi.org/10.1007/s40279-015-0460-2.

[19] Massey, D. C., Vincent, J., Maneval, M., Moore, M., & Johnson, J.T. (2004). An analysis of full range of motion vs. partial range of motion training in the development of strength in untrained men. *Journal of Strength and Conditioning Research, 18*(3), 518-521.

[20] McGuigan, M., & Ratamess, N. (2009). *Applied Anatomy and Biomechanics in Sport* (Second ed., pp. 119-154) (T. R. Ackland, J. Bloomfield, & B. Elliott, Eds.). Champaign, IL: Human Kinetics.

[21] McGuigan, M. R., & Wilson, B. D. (1996). Biomechanical analysis of the deadlift. *Journal of Strength and Conditioning Research, 10*(4), 250-255.

[22] McLaughlin, T. M., Dillman, C. J., & Lardner, T. J. (1977). A kinematic model of performance in the parallel squat by champion powerlifters. *Medicine and Science in Sports, 9*(2), 128-133.

[23] NCAA. (2021, August 1). *2021-22 NCAA Division II Manual*. https://web3.ncaa.org/lsdbi/reports/getReport/90010.

[24] Neumann, D. A. (2010). Kinesiology of the hip: A focus on muscular actions. *Journal of Orthopaedic & Sports Physical Therapy*, *40*(2), 82–94. https://doi.org/10.2519/jospt.2010.3025.

[25] Nigro, F., & Bartolomei, S. (2020). A comparison between the squat and the deadlift for lower body strength and power training. *Journal of Human Kinetics*, *73*(1), 145–152.

https://doi.org/10.2478/hukin-2019-0139.

[26] Pinto, R. S., Gomes, N., Radaelli, R., Botton, C. E., Brown, L. E., & Bottaro, M. (2012). Effect of range of motion on muscle strength and thickness. *Journal of Strength and Conditioning Research*, *26*(8), 2140–2145. doi: 10.1519/jsc.0b013e31823a3b15.

[27] Ratamess, N. A., Alvar, B. A., Evetoch, T. K., Housh, T. J., Kibler, W. B., Kraemer, W. J., & Triplett, N. T. (2009). Progression models in resistance training for healthy adults. *Medicine & Science in Sports & Exercise, 41*(3), 687-708. doi:10.1249/mss.0b013e3181915670.

[28] Rhea. M.R. (2004). Determining the magnitude of treatment effects in strength training research through the use of the effect size. *Journal of Strength and Conditioning Research*, *18*, 918-920.

[29] Rhea, M. R., Kenn, J. G., Peterson, M. D., Massey, D., Simao, R., Marin, P. J., Favero, M., Cardozo, D., & Krein, D. (2016). Joint-Angle specific strength adaptation influence improvements in power in highly trained athletes. *Human Movement*, *17*(1), 43-49.

[30] Sands, W. A., Wurth, J. J., & Hewitt, J. K. (2012). The National Strength and Conditioning Association (NSCA): Basics of strength and conditioning manual. https://www.nsca.com/contentassets/116c55d64e1343d2b264e05aaf158a91/basics_of_strength_and_conditioning_manual.pdf.

[31] Schoenfeld, B. J., & Grgic, J. (2020). Effects of range of motion on muscle development during resistance training interventions: A systematic review. *SAGE Open Medicine, 8*, 1-8. doi:10.1177/2050312120901559.

[32] Seo, D., Kim, E., Fahs, C. A., Rossow, L., Young, K., Ferguson, S. L., Thiebaud, R., Sherk, V., Loenneke, J., P., Kim, D., Lee, M., Choi, K., Bemben, D., A., Bemben, M., G., & So, W.Y. (2012). Reliability of the one-repetition maximum test based on muscle group and gender. *Journal of Sports Science and Medicine, 11*, 221-225.

[33] Shurley, J. P. (2020). "Stronger Is Better." *Journal of Strength and Conditioning Research*, *34*(5), 1201–1212.

[34] Suchomel, T. J., Nimphius, S., Bellon, C. R., & Stone, M. H. (2018). The importance of muscular strength: Training considerations. *Sports Medicine, 48*(4), 765-785. doi:10.1007/s40279-018-0862-z

[35] Todd, T. (2012, August 2). Don Reinhoudt. http://ditillo2.blogspot.com/2012/08/don-reinhoudt-terry-todd.html.

[36] Tsatsouline, P. (2005). *Beyond Bodybuilding.* St. Paul, Minnesota: Dragon Door Publications, Inc.

[37] Tweed, L. (2018, October 28). Mechanics of the Deadlift - Don Cundy (1970). http://ditillo2.blogspot.com/2018/10/mechanics-of-deadlift-don-cundy-1970.html.

[38] USA Powerlifting. https://www.usapowerlifting.com/. Accessed: 2.23.2022.

[39] United States Strongman Inc. https://www.unitedstatesstrongman.com/uss-records. Accessed: 2.17.2022.

[40] Verkhoshansky, Y., Siff, M. (2009). *Supertraining* (6th Ed.) Rome, Italy: Verkhoshansky.

[41] Whaley, O., Larson, A., & DeBeliso, M. (2020). Progressive movement training: An analysis of its effects on muscular strength and power development. *The Sport Journal*, *21*, 1-14.

[42] Zatsiorsky, V. (2012). Biomechanical basis of strength training. http://ojs.ub.uni-konstanz.de/cpa/article/view/2808.