International Journal of Strength and Conditioning

Comparison of Muscle Activation and Range of Motion between the Traditional and Landmine Romanian Deadlift

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ABSTRACT

Purpose: The purpose of this study was to compare levels of trunk, upper- and lower-body muscle activation, and trunk and hip range of motion between the traditional (TRDL) and landmine Romanian deadlift (LRDL).
Methods: Nine male and seven female participants (age: 23.2 ± 5.3 yrs; height: 171.7 ± 8.8 cm; weight: 78.7 ± 17.5 kg) with a minimum of six months resistance training experience volunteered and completed the study. Muscle activation and trunk and hip range of motion were time synchronized during the RDL exercises. Maximum voluntary isometric contraction (MVIC) using electromyography (EMG) was assessed for each muscle group (middle trapezius, latissimus dorsi, erector spinae, gluteus maximus, and biceps femoris) for data normalization. The subjects completed three repetitions at an 8RM load for each RDL. Electromyography and inertial measurement unit measures were analyzed using the SPM 1d Version 0.4 for 1-dimensional Statistical Parametric Mapping package for Matlab. Paired t-tests were used to compare the TRDL and LRDL measures during the concentric and eccentric phases with the level of significance set a priori at $p < 0.05$.
Results: No significant EMG differences were found in all analyzed muscle groups during the eccentric and concentric phases. Hip and lumbar flexion were also not significantly different between the exercises.
Conclusions: Using a similar relative intensity, the TRDL and LRDL produce similar levels of activation in the trunk, upper-body, and lower-body muscle groups. The amount of posterior shifting of the center of mass is similar between the exercises indicated by the similar range of hip and trunk motion.
Practical Applications: The data indicate that both RDL exercises can be used interchangeably with no difference in muscle activation or hip and lumbar range of motion.

INTRODUCTION

The traditional Romanian deadlift (TRDL) is a resistance training exercise intended to target primarily the hip extensors (13,15). With the knees held in a slightly flexed position while maintaining a neutral trunk, hip flexion and extension occurs to primarily isolate activation of the hip extensor musculature. In contrast, hip and trunk extensors are involved as the load's line of gravity increases by moving further from the hip's axis and vertebral column while the weight is held under the shoulder joint during hip flexion (11). Scapula and glenohumeral stabilizers and glenohumeral extensors are also required to hold the load during the TRDL, yet no known study has investigated the level of activation from the involved shoulder muscle groups.

The TRDL is a weight-bearing exercise implemented to achieve a measure of specificity with the use of hamstring activity during weight-bearing sports. In addition, the TRDL is also added to resistance training programs for hamstring development due to low activation found in the squat (7). The greater hamstring activation found in the TRDL in comparison to the squat is possibly a result of reciprocal inhibition from high quadricep activation during the squat (7,18,28). However, the TRDL produced lower gluteus maximus (GM) activation in comparison to the rear-foot elevated split squat (18) and lower hamstring activation compared to levels found during the leg curl (9,17,22,26) and Nordic exercise (9,26). The TRDL's narrow, anterior-posterior base of support creates a degree of instability, which may attenuate maximum muscle activation and force production by limiting the amount of weight capable of being lifted. Thus, investigating a more stable variation of the exercise is prudent to consider.

A modification of the TRDL is the landmine RDL (LRDL). The exercise provides anterior-posterior stability by anchoring the end of the bar and is performed by straddling and holding the other end of the bar. The lifter performs the RDL as described but is free to counterbalance the anterior load with a posterior translation of the hips as much as needed without becoming unbalanced. The LRDL has a large anterior-posterior base of support measured from the toes to the anchored end of the bar. The improved stability from this variation of the TRDL may allow the lifter to use greater absolute loads and increase muscle activation in the primary muscle groups, which is supported in previous research comparing stable and unstable exercises (5).

While the hip extensors are the primary muscles intended to train with the TRDL, less is known about the level of activation from the trunk and upper-body musculature. As noted, the trunk extensors are isometrically activated to maintain a neutral posture. Yet, training several weeks with the stiff-legged deadlift did not improve lumbar torque could indicate low muscle activity in resistance-trained, young-adult males (11). In addition, the glute-ham raise was found to produce greater trunk extensor muscle activation in comparison to the TRDL in resistance-trained, young-adult males (16). Further, standing on a step to increase the range of motion was shown to increase lumbar activation of the TRDL in highly-trained, young-adult male, competitive body builders (6). However, reaching this bottom position may not be possible with heavy loads due to a lack of hip flexibility. An increase in trunk flexion may occur to lower the bar near the floor level, which has potential to increase stress on the low back tissue and vertebral discs. Thus, it is reasonable to investigate modifications of the TRDL that may enhance trunk extensor activation with variations of the TRDL that can be executed with proper technique.

During the TRDL the shoulder girdle must be stabilized to hold the load. Shoulder flexion and extension also occurs at the glenohumeral joint during the TRDL. The load is held suspended vertically under the shoulder likely limiting the need from the shoulder prime movers (i.e. latissimus dorsi) to produce shoulder flexion and extension, but the level of activation placed on the scapula stabilizers (i.e. trapezius) and prime movers is yet to be determined warranting further investigation. In contrast to the TRDL, during the LRDL the load is rotating in an arc motion while the hips are capable of shifting more posterior to counterbalance the load. These differences appear to require greater effort from the shoulder musculature to hold load and control shoulder flexion and extension.

The LRDL is a more stable variation of the TRDL that has the potential to increase muscle activation of the lower-body, trunk and upper-body muscle groups with the use of greater loads and maximum effort from the prime movers. The differences in grip, bar motion, and mass distribution to counterbalance the anterior load also has the potential to impact muscle activation patterns. Therefore, the purpose of this study is to compare muscle activation patterns of the hip, trunk and shoulder during the TRDL and LRDL using the same relative intensity. The secondary aim of the study is analyze the hip and trunk range of motion between the exercises due to the ability to increase posterior translation of the hips during the LRDL without loss of stability.

METHODS

Subjects

Sixteen subjects (N = 9 males, 7 females) with a mean age, height, and weight ± standard deviation of 23.2 ± 5.3 yrs, 171.7 ± 8.8 cm, 78.7 ± 17.5 kg, respectively volunteered and completed the study. To be included in the study the subjects were required to be currently active in resistance training for a minimum of six months. The subjects had 3.3 ± 2.7 yrs of resistance training experience. The subjects had to be currently participating in resistance training at a minimum of one time per week. Most subjects trained two to three times per week. All subjects had previous experience training with the TRDL exercise using a free-weight barbell. The subject's 8RM strength was 69.9 ± 21.7 kg on the TRDL and 68.6 ± 20.9 kg on the LRDL. Those with previous lower extremity injury or medical condition that limited maximum effort to complete a maximum strength assessment were excluded. The study was approved by the university's IRB. All subjects were verbally informed of the benefits and risks associated with participation before reading and signing the informed consent form.

Study Design

A cross-sectional study was completed to assess the level of muscle activation in the upper body, trunk, and lower body using the same relative intensity during the TRDL and LRDL. The subjects completed three sessions (familiarization, strength assessment, and EMG/kinematic data collection). EMG was normalized by assessing the maximum voluntary isometric contractions (MVIC) for each muscle group prior to the EMG data collection in the same session. EMG was compared during the entire range of motion during the eccentric and concentric contractions. Trunk and hip motion were also compared between exercises. All sessions were completed in the Clinical Biomechanics and Physiology Lab at approximately the same time of day for all subjects.

Procedures

Familiarization Session: After reading and signing the informed consent form, the subject's age, height, weight, and training experience were collected during a familiarization-session. A 10-min, dynamic warm-up with light stretches took place prior to execution of the exercises. Instructions for correct technique on the TRDL were provided by the investigators. Based on the subject's estimation of his or her 8RM load on the TRDL, two warm-up sets of 3-5 repetitions using light loads (~40-50% estimated 8RM) were completed. After correct technique was demonstrated, the subject completed three repetitions using a load estimated to be 75% 8RM to confirm correct technique occurred at heavier loads. The same procedure was followed during practice of the LRDL.

Strength Test Procedures: An 8RM was assessed on the TRDL and LRDL after a minimum of 48 hours of rest following the familiarization session. A 10-minute, dynamic warm-up and light stretches occurred prior to the strength assessment. The order completing the TRDL and LRDL was randomized with a 10-min rest between exercises. For each exercise the same procedure used during the familiarization session for the warm-up sets was used for the strength assessments. To determine the 8RM, NSCA guidelines were followed by completing eight repetitions with progressing load each set (24). Each lift was performed with a hip-width stance, knees static in a slightly flexed position, neutral trunk, and approximately 90-105° of hip flexion and extension. The anterior load was counterbalanced with a posterior shift of the hips. The bar with added weight was held in the hands with the elbows completely extended. The exercises started in the upright, standing position and occurred with isolated hip flexion until the weight touched a five-cm pad positioned on the floor and ended with the return to the standing position. The TRDL (Figure 1A) was held with a shoulder-width and pronated grip while the LRDL was held with a right-hand, neutral baseball-bat grip while straddling the bar. For the LRDL, the opposite end of the bar was fixed allowing the bar to rotate (Figure 1B). The toes were positioned 10-25 cm behind the first plate during the LRDL and controlled for each subject. Proper technique was qualitatively assessed and required for a successful trial. All measures of strength were assessed within three sets.

EMG and Kinematic Data Collection: After a minimum of 48 hrs of rest, EMG data was collected for both exercises in the same session. After a 10-minute dynamic warm-up and light stretches, the participant's skin was prepared for sensor placement by shaving, abrading, and cleansing with isopropyl alcohol. Using double sided tape, wireless EMG sensors (Trigno Avanti, Delsys, Boston, MA, USA) were then placed on the right middle trapezius (MT) between T2 and the medial border of the scapula (10), latissimus dorsi (LD) at one cm lateral to inferior border of the scapula (20), erector spinae (ES) at three cm from L3 spinous process (3), GM (18) between the greater trochanter and sacrum, and biceps femoris (BF) (18) between the ischial tuberosity and lateral epicondyle of the tibia on the muscle belly parallel to the longitudinal axis of the muscle. To minimize sensor shifting and ensure consistent conductivity, elastic wraps were placed over the electrodes with light pressure.

Kinematic data were measured with inertial measurement unit sensors (IMU) that were calibrated while the participant faced 0° North in the cardinal direction. The sensors used to measure

Figure 1A. TRDL Traditional Romanian Deadlift

Figure 1B. LRDL Landmine Romanian Deadlift

EMG of the MT, ES, and BF along with placement of one sensor on the sacrum also measured lumbar and hip flexion and extension. The IMU and EMG data were recorded simultaneously and later synchronized during a manual process within the software.

For normalization of the data, MVICs were conducted for each muscle. After a five-min rest, the subject completed three repetitions using an 8RM load with each exercise in random order with a five-min rest between each exercise. All EMG recordings took place in one session.

Instrumentation and Data Processing: The Motion Monitor software was used to time synchronize the EMG and IMU data and for initial data processing. EMG data were collected at 2000 Hz and processed using a 10-500 Hz bandpass filter. The root mean square amplitude was exported for each muscle. All MVICs were collected with the subject lying prone on an examination table and the body immobilized using a strap that was secured to the table and with manual resistance where necessary for stabilization. A five-second MVIC was executed with a gradual increase to maximum effort after one to three seconds. The highest one-second EMG recording was used as the MVIC for analysis. All tests involved securing the body to the table using a strap around the hips except the GM, which took place with the strap around the lower back. BF MVIC was collected with the hip and knee extended (22) using a strap to secure the ankle at the Achillies tendon. While the hip was extended and the knee flexed at 90° during the GM MVIC (27), a strap secured the hips to the table and applied the resistance at the posterior, distal femur. LD MVIC occurred with the shoulder at 0° while isometrically producing shoulder extension against manual resistance at the wrist (20). The MT was assessed with the shoulder abducted to 90° and externally rotated while attempting horizontal abduction against manual resistance at the wrist (10). The ES muscle was assessed with the upper body horizontal to the floor with the trunk extended over the edge of the table and against manual resistance at the upper back (3).

Kinematic data were collected at 100 Hz and used to determine the start and end of each eccentric and concentric phase of the exercises. The eccentric phase began when the participant lowered the bar to the ground and hip flexion increased. The concentric phase began during the ascent after reaching the bottom position. Event markers were manually placed in the activity file to denote the start and end of each eccentric and concentric phase. Data were further processed using Matlab version R2023b (MathWorks, Inc., Natick, MA). The EMG and IMU data from each phase (eccentric, concentric) were time normalized from 0-100%.

Statistical Analysis: EMG and IMU measures were assessed using the spm1d Version 0.4 for 1-dimensional Statistical Parametric Mapping (SPM) package for Matlab (21). Data was assessed for normality using the Kolmogorov-Smirnov test. The data was not normally distributed. Non-parametric paired SPM t-tests were used to compare the TRDL and LRDL EMG and IMU data during the concentric and eccentric phases. The level of significance was set a priori at p <0.05. To determine the magnitude of difference between the TRDL and LRDL, Hedges' g effect sizes were calculated and interpreted as large (>0.80), moderate (0.50-0.79), small 0.20-0.49), and trivial (<0.19).

RESULTS

There were no statistically significant differences for EMG or kinematic variables between the TRDL and LRDL during the eccentric or concentric phases (p > 0.05). (Figures 2 and 3, Table 1). TRDL and LRDL means, standard deviations and effect sizes during the concentric and eccentric phases are reported in Table 1. Lumbar and hip flexion data with 95% confidence intervals during the eccentric and concentric phases are reported in Figure 2. Eccentric and concentric EMG data with 95% confidence intervals are reported in Figure 3. Effect sizes for the EMG, lumbar flexion, and hip flexion data were trivial to small.

DISCUSSION

The primary finding of this study was that the LRDL and TRDL produced similar levels of muscle activation in all muscle groups using the same relative intensity. Relatively moderate to high activation was determined to occur in all muscle groups using an 8RM load. In addition, no significant differences were found in hip and trunk range of motion.

The levels of GM, BF, and ES activation found in our study are similar to levels found in previous studies that analyzed the TRDL using similar relative loads (~8RM) (1,6,13,26,28). In comparison to our data, lower activation levels (21-38%) were found across these muscle groups when using 50% 1RM supporting the load-dependent relationship with activation level (8). In agreement with previous research (1,6,8), the ES produced the highest mean muscle activation in our study (~95%) followed by the BF activation (~63%) and GM (~51%). Research comparing the difference between GM and BF activation is mixed, in part, due to differences in exercise type, technique and load (6,8,13,26). Some studies report higher hamstring activation (8,13) while others found higher GM activation (6,26). Andersen et al. (1) found very similar EMG levels in the GM and BF. The effect sizes for the ES, GM, and BF were small compared across exercises. Yet, the relatively small differences in GM and BF activation found in our study is also supported by previous research (1,6,8,13,16). However, caution in making definitive conclusions from these comparisons must be taken into consideration since results are derived from

Table 1. Means, standard deviations, and effect sizes for the eccentric and concentric phases of the TRDL and LRDL exercises.

	Eccentric			Concentric		
	TRDL Mean + SD	LRDL Mean + SD	ES	TRDL Mean + SD	LRDL Mean + SD	ES
Lumbar Flexion (°)	4.6+14.2	4.9+16.0	0.020	5.5+15.7	6.0+17.7	0.030
Hip Flexion (°)	58.7+59.0	63.0+63.2	0.070	55.3+36.4	59.7+34.9	0.123
Middle Trapezius (% MVIC)	69.4+58.4	75.2+65.1	0.094	75.4+67.4	67.2+60.5	0.128
Latissimus Dorsi (% MVIC)	50.1+33.9	55.3+29.7	0.163	53.2+33.4	70.0+46.5	0.415
Erector Spinae (% MVIC)	65.8+49.0	81.9+55.7	0.307	100.0+78.6	129.6+95.2	0.332
Gluteus Maximus (% MVIC)	33.4+31.6	37.7+27.1	0.146	59.2+36.9	72.0+44.3	0.314
Biceps Femoris (% MVIC)	40.8+23.0	52.0+32.4	0.399	72.3+47.1	85.1+59.2	0.239

Effect size (ES), landmine Romanian deadlift (LRDL), maximum voluntary isometric contraction (MVIC), standard deviation (SD), traditional Romanian deadlift (TRDL)

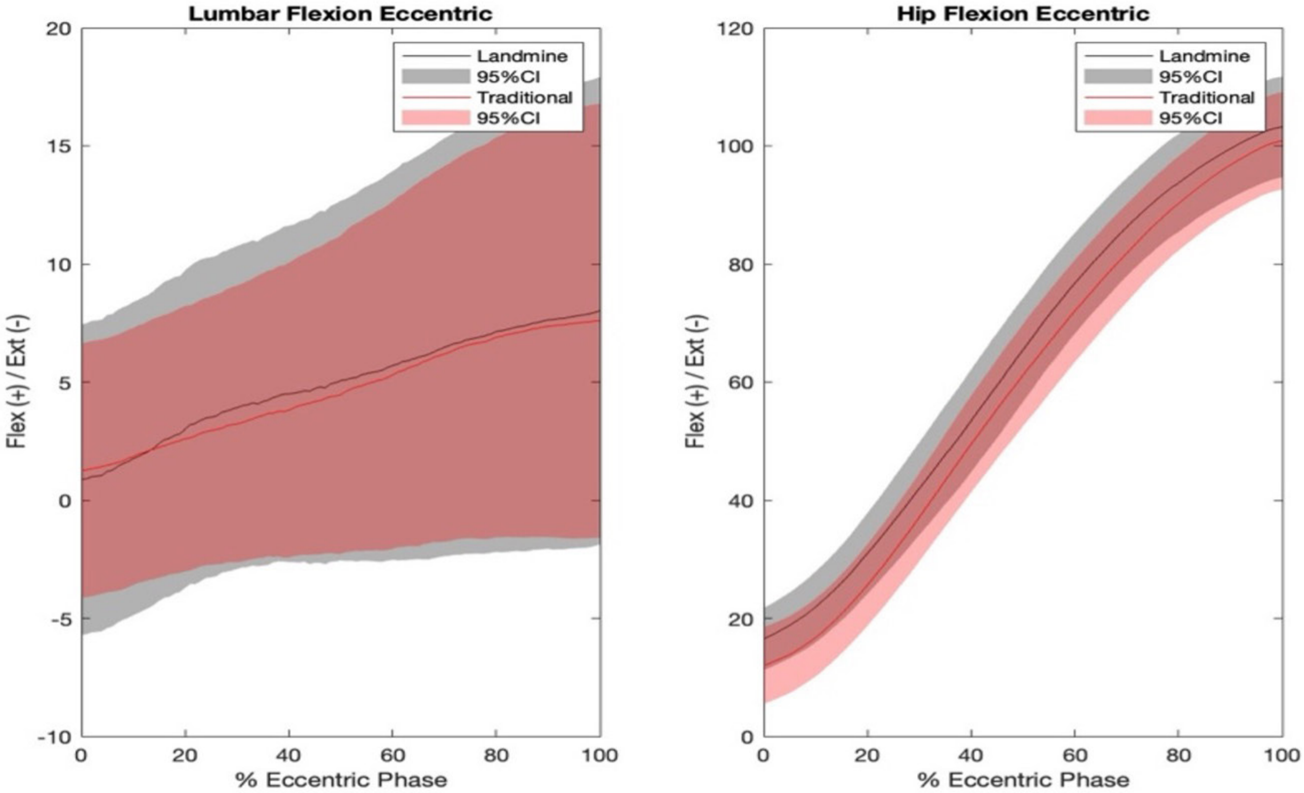

Figure 2A. Lumbar and hip flexion and extension angles during the eccentric phases for the TRDL and LRDL

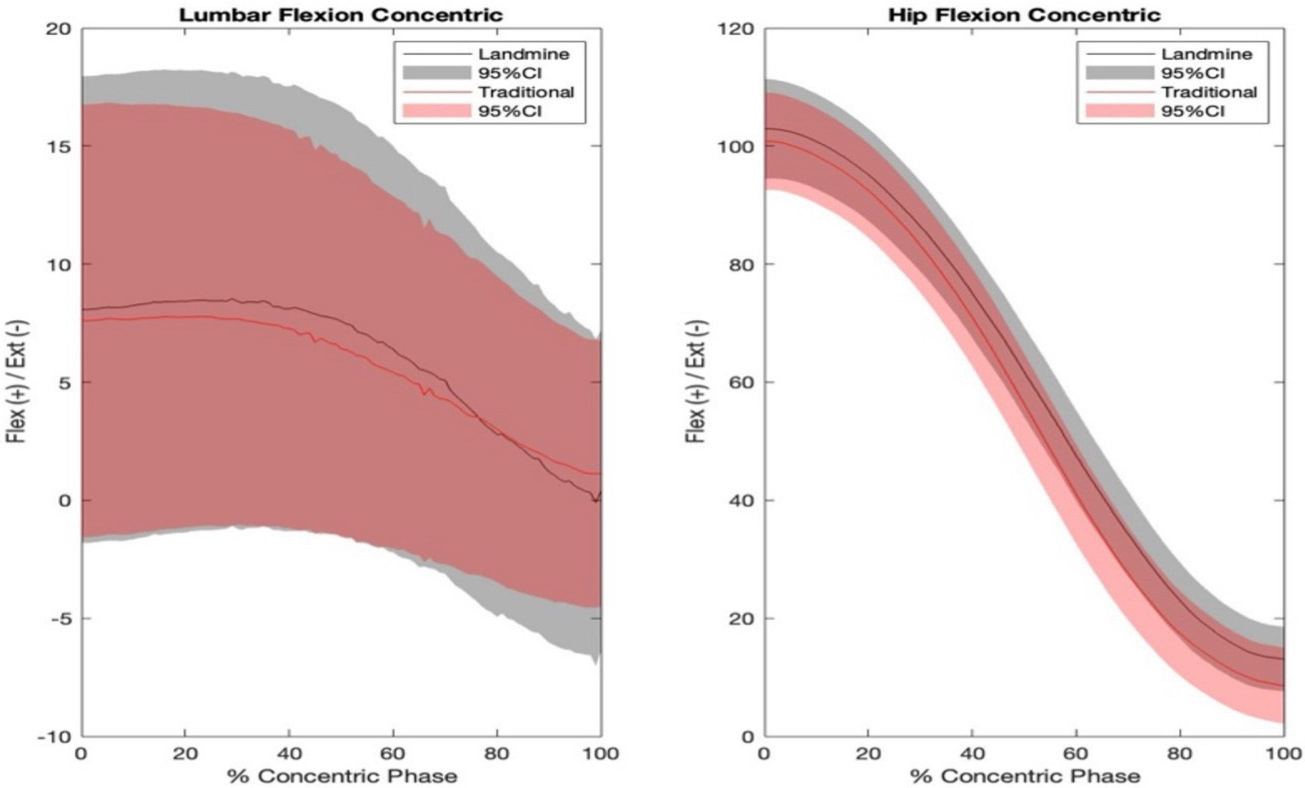

Figure 2B. Lumbar and hip flexion and extension angles during the concentric phases for the TRDL and LRDL

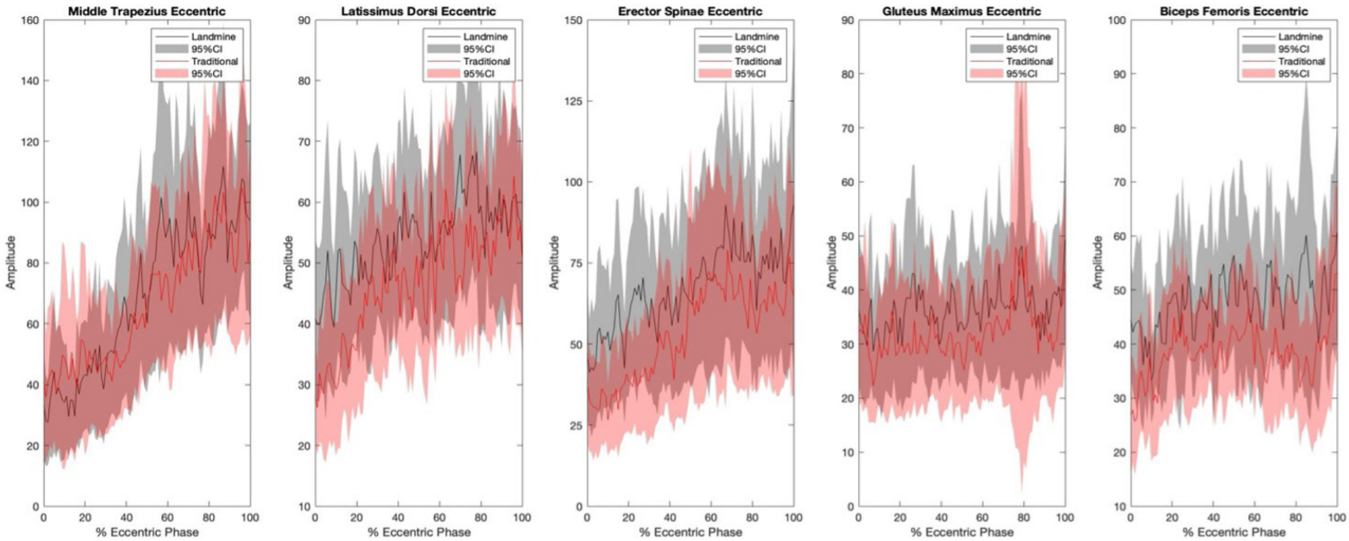

Figure 3A. EMG RMS amplitudes (% MVIC) and Confidence Intervals (CI) during the eccentric phases for the TRDL and LRDL

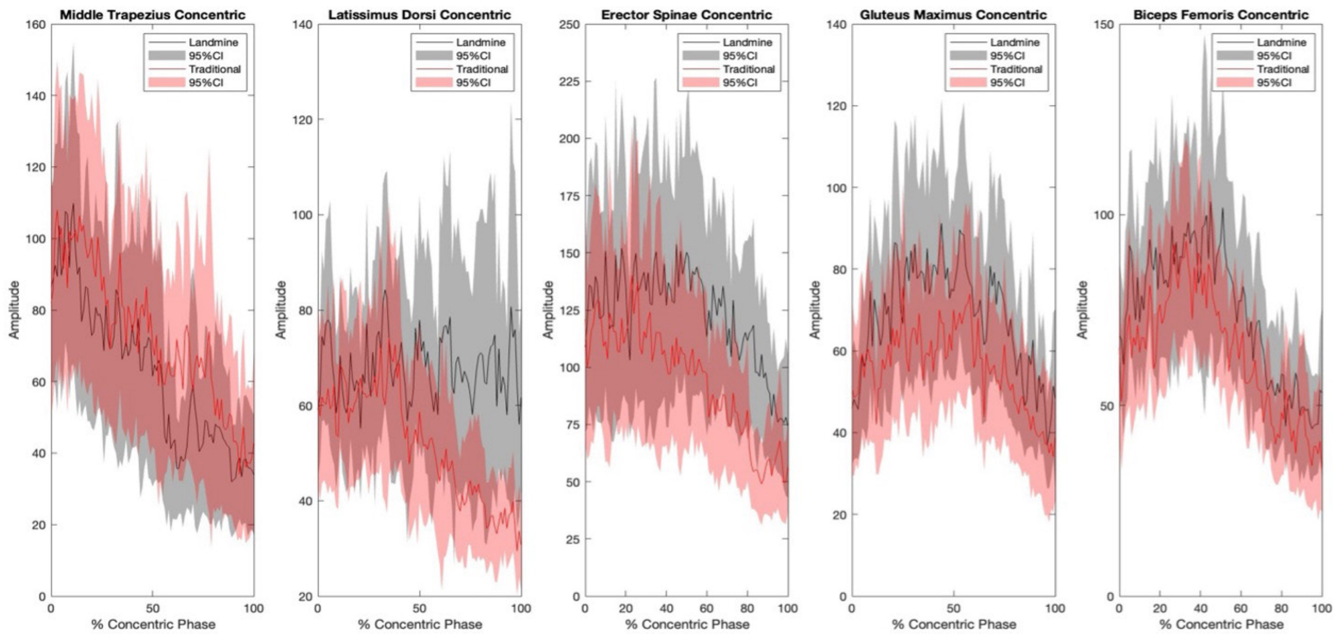

Figure 3B. EMG RMS amplitudes (% MVIC) and Confidence Intervals (CI) during the concentric phases for the TRDL and LRDL

MVIC methods that vary among the studies.

Our study compared muscle activation at the same relative intensities. The LRDL provides a greater anterior-posterior base of support, thus is arguably a more stable exercise. Resistance exercises that are more stable have been shown to increase force production (5); however, the exercise type, load, and the type of altered stability are factors that require consideration. Based on a difference in stability, we hypothesized that greater loads would be lifted on the LRDL, consequently producing greater muscle activation. However, the subjects' 8RM were not statistically different between the exercises (TRDL = 69.9kg versus LRDL = 68.6kg). The TRDL is a linear motion while the LRDL involves rotation of the load, which includes torque as the resistance. The magnitude and center of mass of the load on the TRDL is unaffected by the position of the weights on the bar but as plates are added to the end of the LRDL bar, the distance of the weight's center of mass increases from the axis increasing the resistance torque in addition to the added weight. For this reason, the magnitude of the loads cannot be directly compared based solely on absolute load.

With a large anterior-posterior base of support in the LRDL, we hypothesized that subjects would produce a greater posterior shift of the hips to counterbalance the anterior load (Figure 1A and 1B). Mean peak hip flexion was greater in the LRDL (103 vs 98°), but this difference was not statistically significant with a trivial effect size. No difference in lumbar motion (~7°) occurred between the exercises with both revealing that a relatively neutral posture was maintained. The bottom position of the lift was controlled by instructing the subjects to touch the weight to a two-inch thick pad placed on the floor before returning to the starting position. As knee position remained static, a greater posterior shift of the hips would likely create greater hip flexion. In comparison to the TRDL, the LRDL can be performed with greater posterior hip displacement while maintaining anterior-posterior stability since the mass is within the base of support (end of the bar behind the lifter to the toes). Previous research indicated that increasing hip range of motion by standing on a step during the TRDL increases lumbar activation (6). In addition, Baroni et al. (2) revealed that training through the full range of motion produced greater muscle damage, which could lead to increased strength and hypertrophy with optimum recovery. Yet, our difference in hip flexion was not significantly different and did not demonstrate significant differences in muscle activation. Allowing the subject to lower the weight to his or her maximum range may have influenced muscle activation levels, but this speculation requires further investigation. While muscle activation level may not predict the extent of adaptation with training, Schoenfeld and Grgic (23) concluded in a systematic review of the research that some evidence indicate that full range of motion compared to partial range in the lower body leads to greater improvement in hypertrophy, but other factors such as training status, intensity and volume, and muscle group may also affect the level of adaptation and should be considered. Further analysis is needed to determine if increasing posterior hip displacement and range of motion during the LRDL would lead to greater trunk and hip muscle activation, strength and muscle hypertrophy.

This was the first study known to compare upper-body muscle activation during variations of the RDL. While shoulder range of motion was not measured, greater shoulder flexion occurs as the hips are posteriorly shifted during the LRDL (Figure 1A and 1B). This load must be resisted eccentrically by the LD and concentrically during extension of the shoulder joint as the weight is held more in front of the body compared to the TRDL. In contrast, the bar path is linear during the TRDL while suspended directly under the shoulder during hip flexion as the trunk approaches a horizontal position. Thus, we hypothesized that less effort and muscle activation would be required to hold a naturally suspended load during the TRDL. However, the difference observed between the exercises was not statistically different. The difference between the lifts was greater in the top half of the exercises, but the effect size across the complete range of motion was small. As noted for the trunk and hip muscles, the effect of different degrees of hip flexion on LD activation needs further study.

Relatively high LD activation occurred during the LRDL (55-70%) and TRDL (50-53%) across eccentric and concentric phases, respectively. In comparison, previous studies showed that the isometric (35%) (19) and dynamic (79-94%) (30) inverted row produced a wide variation in muscle activation, which is an exercise specifically designed to train the LD. Low LD activation (10-40%) was found during dumbbell carries in the overhead and suitcase position with 15-45% body weight (4). Further, Sperandei et al. (25) found 50 and 90% LD activation during eccentric and concentric contractions, respectively during the lat pulldown exercise at 80% 1RM. Similar to our findings, Fujita et al. (12) found ~70% LD activation in the seated row at 70% 1RM. However, the effect of training with the TRDL and LRDL on potential neuromuscular adaptations requires further investigation.

Similar MT activation occurred during the LRDL (67-75%) and TRDL (69-75%) across the eccentric and concentric phases. Lower MT activation occurred during the body weight, inverted row (35-45%) (30) and while carrying loads of 25-45% body weight (29-41%) in the upper and lower trapezius. Lower MT activation (20-36%) was also found in the seated row and lat pulldown at a 10-12 RM load compared to our data (14). Greater MT activation (~90%) took place for the inverted row while adding 10% body weight and executing the exercise on one leg and an unstable surface (29). Based on previous studies, our data indicate that supporting relatively high loads in the hands during the LRDL and TRDL evokes relatively high activation from the MT to support movement and stabilization of the scapula.

Several existing limitations are important to be noted. This study had a small sample size. The differences revealed may have been statistically significant with a larger sample and more homogenous sample of highly resistance-trained subjects. Muscle activation from surface EMG may not reflect the level of activation from all motor units in the possible pool. Surface EMG magnitude may also not predict the long-term training adaptations. Results may also vary at other workloads and volume of repetitions completed. Different results may also occur in stronger subjects who have a higher level of training experience. Prior to this study all participants had TRDL training experience, but no one previously trained using the LRDL. Sensor shifts are possible with surface EMG that may affect conductivity; therefore, methods were taken to minimize this taking place using double sided tape and elastic wraps. Finally, as noted, the MVIC method used must be considered in the interpretation of the muscle activation levels.

CONCLUSION

The LRDL and TRDL produced similar muscle activation levels in the hip and trunk extensors and in the LD and MT. While it was expected to find relatively high levels of activation in the hip and trunk extensors, we also found relatively high levels of activation in the LD and MT. While relatively high muscle activation occurred with each muscle during both exercises, the effect that these exercises may have on training adaptations is not possible based on our data. Thus, training studies are needed to further understand long-term improvements. A neutral trunk posture was able to be maintained with each exercise using an 8RM load. The difference in hip range of motion was not significant suggesting similar posterior shift of the hips took place to counterbalance the load.

FUTURE RECOMMENDATIONS

During practical use and further investigation, the biomechanical differences must be considered. The TRDL is linear with resistance determined by the added load. The LRDL is an angular motion with resistance determined by added load and the change in the load's center of mass. Position of the joint axis relative to the load's center of mass must be considered for both exercises. With greater anterior-posterior base of support, the LRDL's technique has the potential to be significantly altered by counterbalancing the load with greater posterior hip displacement compared to the TRDL. Greater counterbalancing has the potential to increase hip and shoulder range of motion and the magnitude of the resistance. Further studies analyzing the effect of increasing the posterior shift of the hips to counterbalance the anterior load on hip and shoulder range of motion and muscle activation is warranted. Training studies implementing the TRDL and LRDL are also needed to determine potential adaptations on strength and hypertrophy. Finally, we recommend investigating similar designs with various training loads and inclusion of subjects with more advanced resistance training experience and greater levels of strength in future studies.

CONFLICTS OF INTEREST

The authors report no conflicts of interest

FUNDING

No funding sources were used to complete this study

ETHICAL APPROVAL

Ethics for this study were approved in line with University's ethics procedure. All subjects were verbally informed of the benefits and risks associated with participation before reading and signing the informed consent form.

DATES OF REFERENCE

Submission - 06/05/2024
Acceptance - 12/12/2024
Publication - 09/05/2025

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