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Effects of a Postural Restoration Focused Intervention on Muscle Activation During Deadlifts

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Effects of a Postural Restoration Focused Intervention on Muscle Activation during Deadlifts
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ABSTRACT

EFFECTS OF A POSTURAL RESTORATION FOCUSED INTERVENTION ON MUSCLE ACTIVATION DURING DEADLIFTS

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The purpose of this study was to determine the efficacy of implementing two Postural Restoration exercises and relating principles on deadlifts using a hexagonal barbell. Specifically, we aimed to examine the effects of the intervention on muscle activation and the location of the ground reaction force (GRF) center of pressure. Sixteen subjects (age 18-35 yrs.; male (n=14); female (n=2)), with at least 1 year of deadlifting experience, were randomly assigned into a control and intervention group (both n=8). Both groups performed two sets of three repetitions of deadlifts at 50% and at 80% of their estimated one repetition maximum (1-RM). The intervention group received a Postural Restoration inspired breathing exercise routine after three sets, while the control group rested. The deadlift tests were then repeated. We found no significant muscle activation differences for the intervention group for the back extensors, gluteus, hamstrings (biceps femoris long head and semitendinosus), or oblique activation during the hexagonal bar deadlift ($p>0.05$). The anteroposterior center of pressure waveforms demonstrated a more posterior force for the right foot post intervention with a 50% 1-rep max load, occurring during the first 25% of the concentric phase ($p<0.05$). Based on our lack of significant findings, short-term non-manual PRI interventions and coaching does not appear to positively affect deadlift mechanics.

DEDICATION

This thesis is dedicated to my family first and foremost. Without their constant support and love, I would never have had the opportunity to work on a thesis. Also, this thesis is dedicated to the Postural Restoration Institute, and trying my best to help preserve and further the science of PRI. PRI helped me reclaim my body and life, and it has helped me make sense of the events in my life. I tried my best to stay true to what PRI is throughout this work.

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CHAPTER 1 INTRODUCTION

The deadlift is a very popular exercise in the realm of fitness and sport preparation, from recreational exercisers to professional athletes. Deadlifts are employed in strength programs to train hip, knee and back strength (Escamilla et al., 2002). Deadlifts are not limited to strength and power training, as they are used in physical rehabilitation programs as well (Escamilla et al., 2002). The conventional deadlift and sumo deadlift are the two most researched variations; however, interest is budding in the hexagonal bar variation (Camara et al., 2016). Bar variants (e.g. hexagonal bar) alter the biomechanics and forces applied during the lift, such as applying load more equally among the knee, torso and hip when compared to the conventional deadlift, thus bar type utilized for deadlifting is an important consideration (Camara et al., 2016). Performing the conventional deadlift will result in significantly more muscle activation of the erector spinae muscles, as well as the hamstrings (Camara et al., 2016). Furthermore, the hexagonal bar deadlift elicits increased activation of the quadriceps and increased force, power, and velocity generated during the lift compared to conventional (Camara et al., 2016).

Biomechanical Overview of the Deadlift

The deadlift exercise begins in a squat position with a barbell close to the lower legs and the hands grasping the bar in an alternated grip (Swinton et al. 2011). The deadlift is executed by concentrically contracting extensor muscles surrounding the lower back, hip, knee, and ankle joints until the lifter reaches an erect standing position (Swinton et al, 2011; Schellenberg et al., 2013). Once the lifter reaches an erect standing position with the bar, lifters either lower the bar back to the ground, or drop the weight. The eccentric phase of the deadlift, where the lifter reverses the concentric phase, ends with the lifter in the same starting position (Bezerra et al., 2013).

The starting position of the deadlift follows a similar pattern, regardless of bar choice, with the hips, knees, and ankles flexed (Swinton et al., 2011). The gluteus maximus, erector spinae, hamstrings, quadriceps, rhomboids, trapezius, deltoids, and finger flexors are focal muscles in performing a deadlift (Schellenberg et al., 2013). The deadlift allows for very heavy loads to be lifted compared to other lifts, which makes it an excellent lift to increase overall muscular strength (Camara et al., 2016). However, these heavy loads lead to large compressive forces placed on the lumbar spine (national level male and female powerlifters accepting forces from 14,350 to 17,192 N) at the L4/L5 disks (Cholewicki et al., 1991).

Variations of the Deadlift

The conventional, sumo and hex bar deadlift are the three most commonly used deadlift variations. Despite the different bar choices and styles, the deadlift primarily strengthens the thigh, lower leg, and torso musculature (Lockie et al., 2017). The hexagonal bar deadlift is a popular lift among strength and conditioning coaches, mostly because it is thought to be safer than the conventional deadlift; however, little research exists on this variation of the deadlift (Lake et al., 2017). Previous research has found peak moments for the lumbar spine and hip and ankle joints are significantly lower for the hexagonal bar deadlift compared to the conventional deadlift (Swinton et al., 2011). Contrary to the hip and ankle, peak knee moments are significantly larger for the hexagonal bar deadlift compared to the conventional deadlift (Swinton et al., 2011). Additionally, it has been shown that the conventional bar deadlift generates a larger peak moment and more lumbar region muscle activation than the hexagonal bar deadlift (Swinton et al., 2000) (Camara et al., 2016). The additional stress to the lumbar region with conventional deadlifts can be problematic, especially since research suggests the lifetime prevalence of low back pain is as high as 85% for the general population (Trompeter et al., 2017). Over emphasizing back extension while lifting leads to a non-unified lumbar-pelvic-thoracic region (*Postural Restoration Application for Strength and Conditioning Coaches*, Arthur and Hruska, 2013). Over emphasizing back extension can neurologically pattern a person to maintain an elevated ribcage and anteriorly tipped pelvis during activities of daily living, which leads to more lumbar stress (Arthur and Hruska, 2013). This faulty posture can be addressed by recent advances in orthopaedic therapy by the Postural Restoration Institute (PRI), with attention to the ribcage and pelvic positioning, among other factors.

Postural Restoration

PRI is a holistic approach to physical therapy founded by Ron Hruska, PT MPA. Hruska founded the Postural Restoration Institute® in 2000. This approach to therapy respects the natural asymmetries present in the human body, and believes that posture is affected by multiple systems in the body (Boyle, 2006). These influences include the respiratory, nervous, musculoskeletal, oral motor, circulatory, reproductive, digestive, immune and sensory systems (Boyle, 2006). This asymmetrical nature of human beings is referred to as lateralization (https://www.posturalrestoration.com). These asymmetrical patterns are categorized and objectively recognized by PRI trained therapists because they are very predictable. The human body becomes inefficient and pain can develop because of too much lateralization, so PRI exercises are prescribed to reprogram proper reciprocal movement during gait (https://www.posturalrestoration.com). Another very important concept unique to Postural Restoration is known as the Zone of Apposition (ZOA) (Boyle, 2010). The ZOA is functioning optimally when the diaphragm maintains its domed shape during inhalation (Boyle, 2010). When the ZOA is optimal, the ribs will stay down during movement and breathing. Combined with a neutrally aligned pelvis, the person will have a much more streamlined anatomy in the center of their body, meaning that they would not have an excessive lumbar curve and an elevated ribcage. Additionally, an optimal ZOA will allow for both efficient respiration, and for increased activation of the transversus abdominus, which is very important for lumbar stabilization (Boyle, 2010). This is important because low back pain is often times associated with lumbar lordosis (Hodges, 1996).

This lumbar lordosis is a common posture fault people present (Henning et al., 2017). This causes the abdominals to be elongated and weak, and the erector spinae to become shortened and tightened (Sahrmann, 2002). This is not a neutral position for either muscle, as the spinae would need to be inhibited and the abdominals would need to be activated for neutrality to be achieved. Cholewicki et al., 1991, found that a forward trunk tilt during the lift off portion of the deadlift can increase injury risk. Researchers also found that having a more upright trunk during lift off decreases the anterior shear force at L4 and L5 (Cholewicki et al., 1991). Swinton et al., 2011, found that lifters using the hex bar deadlift style are able to stay more in line with the center of their mass throughout the lift when compared to the conventional deadlift. So using a hexagonal bar, as well as having the lifter utilize PRI techniques and principles, which are heavy on obliques, hamstrings and glutes for stability, and inhibiting overactive back extensors, could assist in reducing the risk of back injury while lifting.

Statement of Purpose

The purpose of this study was to determine the efficacy of implementing two Postural Restoration exercises and relating principles on deadlifts using a hexagonal barbell. Specifically, we aimed to examine the effects of the intervention on muscle activation and the location of the ground reaction force (GRF) center of pressure.

Hypothesis

We hypothesized that the PRI intervention will 1) increase hamstring, oblique and glute activation, 2) decrease lumbar extensor activation, and 3) increase force production through the heels and midfoot.

Significance

No peer-reviewed literature exists on Postural Restoration in the exercise realm, specifically in regards to weight lifting. Most PRI based literature addresses physical therapy interventions and outcomes (https://www.posturalrestoration.com); however, it is believed that PRI exercises can be beneficial for athletic performance and longevity (Cuddy, 2014). PRI restores proper respiratory mechanics by aligning the pelvis and ribcage to their optimal positions (Henning, 2017). This restoration of breathing mechanics with respect to human's innate asymmetries can decrease pain, strengthen appropriate muscles, and improve structural alignment (Henning, 2017). This study aims to provide evidence that PRI activities and technique while weight lifting can further decrease lumbar musculature activation when compared to deadlifting without the intervention. This study will also determine if a PRI based intervention can increase muscle activation in the hamstrings and obliques, and if more force production can be elicited through the heels and midfoot while performing the deadlift.

Delimitations

1. All participants will be healthy
2. Participants will be males and females from the age of 18-35 years
3. Participants must have at least one years' experience deadlifting and perform deadlifts at least once per week.

4. Although many PRI exercises exist, we will employ only two exercises. The two chosen exercises directly address breathing techniques, enhancing hamstring activation and internal obliques/traversus abdominus activation.

Limitations

1. Only short-term exercise interventions are being deployed. Therefore, long-term effects are unable to be determined in this study design.
2. We will not perform coaching/cueing during the tested lifts. Coaching/cueing during the deadlift activity could enhance outcome measures of the exercise intervention. However, we aim to determine the efficacy of utilizing these techniques in generalized setting: a person would receive PRI instruction during a physical therapy visit, but would then be required to implement those techniques/instruction on their own during their typical weight lifting periods. The limitation stems from only having one session to implement significant biomechanical changes, instead of multiple sessions with a practitioner.
3. With electrodes secured to the posterior, anterior, medial, and lateral portions of the trunk, we found difficulty implementing the Standing Wall Supported Resisted Reach exercise. Originally, we wanted to use a 90/90 Hip Lift instead of the Standing Wall Supported Resisted Reach. However, the potential for the EMG's moving due to contact with the wall made that a poor choice. Even with the adjustment in exercise choice, the electrodes still irritated the subject and made it difficult to keep the low back flush on the wall for the exercise.

CHAPTER 2 LITERATURE REVIEW

Variations of the Deadlift

As discussed in the introduction, there are many different variations of the deadlift. For this study we will be using the hexagonal bar deadlift, as it is the most suited variant for reduced back extensor activation levels and places the mass of the barbell as close to the center line of the body as possible (*PRI Integration for Fitness and Movement Course,* 2016*)*. Other types of deadlifts are conventional deadlifts, sumo deadlifts, stiff leg deadlift and Romanian deadlifts. There are more variations of deadlifts, those that use kettlebells and machines; however, the focus of the literature review in this thesis will be on deadlifts with either a conventional barbell or a hexagonal barbell.

The conventional deadlift consists of a lifter setting the feet at shoulder width and the arms gripping the bar just outside of the thighs (Piper et al., 2001). In contrast, the lifter has a wider stance and the hands inside the thighs for the sumo deadlift (Piper et al., 2001). Both of these lifts are performed with a straight barbell. The conventional deadlift primarily uses the gluteus, quadriceps, hip adductors and spinal erectors (Bird and Barrington-Higgs, 2010). The sumo deadlift uses the gluteus, quadriceps and hip adductors as well. However, the conventional deadlift has twice the amount of muscle activation compared to the sumo deadlift (Piper et al., 2001). Another common variation is the stiff-legged deadlift, which focuses on the lower back and hamstring musculature (Piper et al., 2001). The lifter maintains straight, locked legs throughout the movement (Piper et al., 2001). The Romanian deadlift, which is defined as different than a stiff-legged deadlift, focuses on the hamstrings and spinals erectors as well, but the knees are flexed at the bottom of the deadlift (Bird and Barrington-Higgs, 2010). The knee become straight once the lifter gets to the top of the deadlift. The Romanian deadlift is thought to be valuable because it teaches proper movement proficiency for weightlifting (Ebel and Rizor, 2002). The Romanian deadlift, when performed properly, sets the posterior chain into a low back-hip hinge, where the hips, buttocks and hamstrings are engaged (Ebel and Rizor, 2002). However, allowing excessive pelvic anterior tilt and ribcage flare up during this low back-hip hinge position would be contraindicated, according to PRI principles (*PRI Integration for Fitness and Movement Course,* 2016). No matter the style of deadlift, excessive back extension or excessive rounding of the back is contraindicated (Piper et al., 2001). It is worth noting that the conventional bar deadlift is one of the top injury-causing weight lifting exercises that can be performed (Keogh and Winwood, 2017).

The hexagonal bar deadlift is a popular alternative to conventional deadlifts, but lacks the depth of research compared to the conventional deadlift. One mechanical advantage of the hexagonal bar deadlift is that the load is closer to the center of the body of the lifter (Swinton et al., 2000). In addition, the hexagonal bar allows for more force, power and velocity than the conventional bar deadlift (Camara et al, 2016). A mechanism for the increase in force and power could be the additional 75% decrease in horizontal displacement for the hexagonal compared to conventional bar (Camara et al., 2016). It is possible that hexagonal deadlifts are a viable variation for athletes, since athletes would want to maximize the qualities of force, power and velocity to improve sport performance. Furthermore, the hexagonal bar deadlift generates a smaller peak moment and less lumbar region muscle activation than the conventional bar deadlift (Swinton et al., 2000) (Camara et al., 2016). Thus, it may be advantageous for anyone with a low back injury or chronic low back pain to choose the hexagonal bar deadlift (Camara et al., 2016). Unless a person specifically wants to strengthen the back extensors, then it seems a hexagonal bar should be used to do the deadlift.

The type of handgrip used during the deadlift is also an important consideration, both outright and with bar constraints (Piper et al., 2001). For the straight bar variations, lifters often choose to use an opposing grip (Piper et al., 2001). An opposing grip is discouraged, as using the same opposing grip repetitively will lead to muscle imbalances in the forearms and back (Piper et al., 2001). The hexagonal bar does not allow for this opposing grip, but requires similar bilateral hand placements/orientations. Although Postural Restoration does not advocate for symmetrical training, the asymmetry gained through an opposing grip is not desired.

Biomechanics of the Deadlift

The deadlift, since it is a compound lift, engages multiple muscle groups at the same time. Similar to most lower-extremity focused exercises, the foot/ankle joint is an important focal point for establishing a solid foundation. During the concentric portion of the deadlift, the ankle joint is quickly plantar flexed, which aids the lifter to transfer power from the ankle to the knee (Van Ingen Schenau, 1989). Previous work comparing ankle mechanics found no peak muscle moment differences comparing the conventional to the hex bar deadlift (Swinton et al, 2011); thus, ankle mechanics appear similar regardless of load placement. In both conventional and hexagonal bar deadlifts, the GRF's moment arms about the ankle joint tend to cause dorsiflexor moments, requiring effort from the plantar flexors to maintain stability (Swinton et al., 2011). Research has also found that as load/resistance increases from 10% to 80% of subject’s 1RM ankle plantar flexion continuously decreased (from 37° to 3°) (Swinton et al., 2011). Thus, although load placement does not appear to influence ankle mechanics, the magnitude of the external load does change the ankle mechanics of the deadlift.

Unlike the ankle, biomechanics of the knee are affected by load placement/bar type utilized in the deadlift (Swinton et al., 2011). When comparing a hexagonal to conventional bar deadlift, maximum knee flexion at the starting position was significantly increased by 6.3º

(Swinton et al., 2011). Additionally, the peak moment of the knee was significantly greater for the hexagonal bar deadlift than the conventional deadlift (Swinton et al., 2011). The conventional deadlift also utilizes more biceps femoris activation during the concentric portion of the lift than the hexagonal bar deadlift (Camara et al, 2016). Whereas, the hexagonal bar deadlift targets the quadriceps more, with significantly greater vastus lateralis activation during the concentric and eccentric portions compared to the conventional deadlift (Camara et al., 2016). Despite the hexagonal bar utilizing more quadriceps than the conventional bar, it is possible slight modifications to technique can alter muscle recruitment during deadlifts. According to PRI principles, if a lifter properly performs the PRI exercises, then the lifter should be able to recruit more hamstring and gluteus maximus activity.

Like the knee, the hip also demonstrates biomechanical differences based on bar choice (Swinton et al., 2011). Previous research has found the hexagonal bar deadlift significantly lowers peak moment at the hip joint during maximal lifts and from 10% to 80% of the 1-RM (Swinton et al., 2011). Multiple studies have found the maximum mean flexion angle of the hip during the conventional deadlift to be between 103° and 124° (Schellenberg et al., 2013; Brown et al., 1985; Escamilla et al., 2001; Escamila et al., 2000; McGuigan et al., 1996). No significant differences were found comparing hip angles between hexagonal and conventional bars (91.8° for hexagonal bar vs. 89.8° or conventional bar; Swinton et al., 2011). Thus, it is likely that load placement of the hexagonal bar deadlifts significantly alters loading from conventional bar deadlifts, which may be important in de-emphasizing lower back joint loads.

The lumbar, pelvis and thoracic regions are all very much involved in the deadlift. These areas are also very important to PRI, especially the coordination and proper alignment of the ribcage and pelvis (*PRI Integration for Fitness and Movement Course, 2016).* During a conventional deadlift at 25% and 50% of bodyweight, the pelvis-lumbar joint range of motions are 19° and 21°, whereas lumbar-thoracic joint range of motions only average ~12° (Schellenberg et al., 2013). Comparing sumo and conventional deadlifts using the same conventional bar, sumo deadlifting significantly reduces L4 and L5 loads by 10% (Cholewicki, et al., 1991). Comparing hexagonal to conventional bars, the straight bar deadlift was found to use greater erector spinae activation, both during the eccentric and concentric portions (Camara et al., 2016). Thus, for training the lower back musculature, then the conventional deadlift may be a better exercise choice than the hexagonal bar deadlift. However, if a lower back injury is present, then the hexagonal bar is a better choice (Camara et al., 2016). For coaches and professionals in the exercise and rehabilitation realms, it is very important to note that biomechanical differences do exist between bar choices for the deadlift. Knowing what the client needs based on injury history and performance demands is essential in choosing the right style of deadlift.

The hexagonal bar deadlift is the bar of choice from PRI perspective due to its placement of load closer to the midline of the body and neutral hand position (*PRI Integration for Fitness and Movement Course, 2016).* PRI, which has mainly been a rehabilitation philosophy, has started to gain traction in the exercise and athletic performance world. People such as Mike Arthur, Director of Strength and Conditioning at The University of Nebraska, Allen Gruver, a PT who is biomechanical consultant for the Arizona Diamondbacks, and Eric Cressey, CSCS who works with multiple top baseball professionals, are all certified or trained in PRI philosophy and techniques (https://www.posturalrestoration.com)(https://www.ericcressey.com). Often times these coaches will use PRI exercises as movement preparations and cool down exercises to get athletes in a better position biomechanically, or to activate the parasympathetic nervous system to improve recovery after a workout (*PRI Integration for Fitness and Movement Course, 2016)*. Even though the practitioners support PRI on evidence-based practice, more randomized controlled trials will be necessary to provide more credence to PRI techniques for weight lifting purposes.

Postural Restoration

The Postural Restoration Institute® was founded in 2000 by Ron Hruska, PT MPA (https://www.posturalrestoration.com). There are 189 Postural Restoration Certified™ professionals, 50 Postural Restoration Trained™ professionals, and just over 80 Postural Restoration Centers™. The Postural Restoration Institute® hosts courses all over the United States and worldwide, conducting over 100 courses per year. These courses include Myokinematic Restoration, Pelvis Restoration, Postural Respiration, Impingement and Instability, Cervical Revolution, Occlusal Cervical Restoration, PRI Integration for Geriatrics, PRI Integration for Baseball, PRI Integration for Fitness & Movement, Postural-Visual Integration, and Vision Integration for the Baseball Player. There are currently 23 peer reviewed research papers related to Postural Restoration. The core concept of PRI is that the human body is asymmetrical (https://www.posturalrestoration.com). Our neurological, circulatory, muscular, respiratory and visual systems are not symmetrical on each side (https://www.posturalrestoration.com). For example, the left lung has 2 lobes, and the right lung has 3 lobes. These asymmetrical differences contribute to a bias for weight shifting to the right and being in right stance more than left stance, which occurs sitting, standing and during the gait cycle. (Henning et al., 2017).

The most common pattern seen in PR is the Left Anterior Interior Chain (L AIC) pattern (Boyle, 2013). The L AIC consists of the diaphragm, iliacus, psoas, tensor fascia latae, vastus lateralis and biceps femoris (https://www.posturalrestoration.com). This polyarticular chain of muscles become overactive, and presents with a pelvis anterior tilted and forwardly rotated on the left (Boyle, 2013). The whole pelvis itself will be turned to the right, which in turn causes the trunk, above T8, to counter-rotate to the left in order to keep the person "straight" (*PRI Pelvis Restoration Course, 2016*). This causes a person to be more lateralized, or shifted over on the right hip (Boyle, 2013). The right hip is in a more internally rotated state, where as the left is in a more externally rotated and anteriorly tipped state (Boyle, 2013) (Henning et al., 2017). The right hip being in an internally rotated state may cause the right gluteus maximus to be in a lengthened and weaker state (Boyle, 2013). This external rotation and anterior positioning of the left hip causes the posterior capsule to become shortened and restricted, and a weakened left hamstring (Boyle, 2009). This is why many of the exercises focus on getting left acetabulum-femoral internal rotation (L AFIR) (Boyle, 2013). Without proper L AFIR, a person will have trouble shifting back over to the left side, because they need to be able to adduct and internally the left hip to properly enter left stance (Boyle, 2013). The L AIC pattern is most often paired with the Right Brachial Chain pattern (R BC) (Henning et al., 2017). The muscles that make up the brachial chain are the anterior-lateral intercostals, deltoid-pectoral, sibson's fascia, traingularis sterni, sternocleidomastoid, scalene and the diaphragm (https://www.posturalrestoration.com). The L AIC pattern rotates the whole pelvis to the right, and to counterbalance this the R BC chain becomes overactive and orients the thorax to the left (Henning et al., 2017). Other identified patterns of polyarticular muscles are the Right Temporal-Mandibular-Cervical Chain (TMCC) pattern and the bilateral Posterior Exterior Chain (PEC) pattern (https://www.posturalrestoration.com)

PRI has developed certain objective tests to determine the patterns that patients present. These assessments are used to determine the triplanar position, which is movement in the sagittal, frontal and transverse planes, of the body (Boyle, 2006). These tests determine whether or not a patient is neutral, which in a PRI sense is defined as optimal diaphragmatic breathing and a body that is physiologically and functionally asymmetrical (Henning et al., 2017). PRI has over 25 tests to determine the triplanar position of a patient, and these are usually administered before each treatment session (Henning et al., 2017). The assessment drives the treatment, and is used to help objectively measure progress. After assessment, treatment in the form of non-manual and manual techniques are implemented. PRI has over 350 non-manual techniques and manual techniques (Boyle, 2006). Non-manual techniques are preferred, since that empowers the patients with the ability to manage and improve their symptoms when not with a trained therapist, which would be the majority of the time (Boyle, 2006). Patient education is also very important, since being conscious of their positioning throughout a 24-hour day is very important to achieving neutrality. It is recommended that patients do the exercises twice a day, and done prior to exercise or sport, as to set the patient up in the best position possible before doing anything strenuous (Boyle, 2006).

A few of the Postural Restoration Institute's® exercises have had randomized controlled trials performed on them. The right side lying respiratory left adductor pull back exercise (RSRLAPB) is a common PRI exercise used to activate left gluteus medius activity and left adductor activity, while repositioning the pelvis to the left (Shori et al., 2017). All participants received a moist heat pack and stretching for 3 weeks, but group 2 also received the RSRLAPB (Shori et al., 2017). The results showed significant changes for group 2 vs. group 1, the RSRLAPB released illotibial band tightness, helped established a normal respiratory pattern, and improved postural asymmetry (Shori et al., 2017). All participants received a moist heat pack and stretching for 3 weeks, but group 2 also received the RSRLAPB. Another study looked at the

90-90 hip lift with balloon and the 90-90 left hemibridge with balloon (Tenney et al., 2013). All 13 participants presented a positive Adduction Drop Test (ADT), which put them in a L AIC pattern or PEC pattern with an underlying L AIC pattern, and had lumbo-pelvic-femoral pain (Tenney et al., 2013). If the patient had a bilateral positive ADT (PEC patient) they did the 90-90 hip lift with balloon, and if they presented a unilateral, positive ADT test (L AIC patient) they did the 90-90 left hemibridge with balloon (Tenney et al., 2013). Each exercise was performed 5 times (Tenney et al., 2013). Immediately post-intervention the ADT was done again, and there was a significant increase in hip adduction angles ($p < 0.01$), as well as a significant decrease in pain levels ($p < 0.01$). There are also numerous case studies that further support the Postural Restoration Institute's® methods. As of 2013, there were four published case studies that showed major improvements in function and pain with PRI techniques used as the intervention (Boyle, 2013). Once a patient gets out of the L AIC pattern, therapists would recommend bilateral stabilization exercises to help maintain the proper pelvic position (Boyle, 2010). The hex bar deadlift seems to be an excellent bilateral exercise choice to help wire in patterns and stabilize the pelvic position gained by performing unilateral PRI exercises. Additionally, one set of five exercises is enough to change these dysfunctions, because of the neuromuscular nature of PRI (Boyle, 2013). This supports our theory that a short-term PRI intervention can change measurable outcomes on the deadlift.

Postural Restoration Principles and the Deadlift

As previously discussed, large L4/L5 disk compression forces can occur during the conventional deadlift (Cholewicki et al., 1991). Elite level world-class lifters can generate lumbar disc compressive forces as high as 36,400 N (Granhed et al., 1987). Naturally, these large compressive forces can lead to acute injury of the lumbar spine (Cholewicki et al., 1991; Granhed et al., 1987). While these compressive forces can be harmful, it is also known that lifting and loading the spine with weight increases bone-mineral density, which can ward off osteoporosis (Layne and Nelson, 1999). Therefore, the deadlift exercise requires attention to balancing positive and negative effects of moving such heavy loads using the lower extremities and trunk.

PRI advocates using a hexagonal bar for deadlifting (*PRI Integration for Fitness and Movement Course, 2016).* The reasons for advocating for the hexagonal over conventional bar are because the hexagonal bar maintains the load close to the center of mass, allows for less lumbar lordosis which decreases lumbar stress, allows the ribcage to descend properly on exhalation, increases oblique activity, decreases sternocleidomastoid activity and allows the lifter to maintain a proper ZOA throughout the lift (*PRI Integration for Fitness and Movement Course, 2016).* PRI does not believe an elevated ribcage, lumbar lordosis, and an anteriorly tilted pelvis are optimal positions to perform the deadlift in (*PRI Integration for Fitness and Movement Course, 2016).* When the diaphragm is functioning optimally, the obliques will activate to properly move the ribcage, while the neck musculature, sternocleidomastoid, will decrease in activity during inhalation and exhalation. PRI does not advocate for the spine to be in flexion, like many of their exercises call for, but a more neutral spine while performing the deadlift (*PRI Integration for Fitness and Movement Course, 2016).* Many of the PRI exercises are meant to be performed with spinal flexion, as this assists in restoring proper ZOA and forces the participant out of an extension-based posture. Evidence is growing in favor of the assertion that patients with chronic low back pain (LBP) share common posture and movement patterns (Aasa et al., 2015). It has been found in standing that chronic LBP patients had more lumbar lordosis than controls (Christie et al., 1995). This lumbar lordosis and elevated ribcage is a posture often assumed by lifters when performing a squat or a deadlift. PRI techniques utilizing exhaling to lower the ribs down and bring the center of gravity over the midfeet and heels. Combining these trunk focused techniques and the hexagonal bar should place the spine in an “optimal” position.

Certain PRI exercises make sense in preparation for the deadlift based on what muscles they activate and what movement patterns they help reinforce. One exercise, the 90/90 hip lift, is one of the best choices for a multitude of reasons: 1) it is one of the most basic exercises and relatively easy to learn, 2) it allows the person to sense the wall (floor) under their feet with specific attention places on feeling the heels, activate hamstrings and glutes to tilt their pelvis, and breathe with a ribcage that descends on exhalation and maintains ZOA upon inhalation. The PRI deadlift technique also requires participants be able to sense weight shift to their heels with hamstring and glute activation, and a ribcage that descends down. However, the 90/90 hip lift was not possible because of the placement of our EMG’s, which would have made it too uncomfortable and potentially damaged the electrodes or interfered with the signal. With this in mind we chose two other PRI exercises to help the participants sense the proper muscles, maintain a neutral pelvis, and set an optimal ZOA during the deadlift. The paraspinal release with hamstrings makes sense because it activates the hamstrings and abdominals at the same time while keeping ZOA throughout the exercise. The SWSRR consists of getting the low back flush with the wall with bent knees, exhaling the ribcage down, reaching forward, and inhaling to get air into the back. Feeling the air expand into their back allows the participants to sense what keeping the integrity of a ZOA is like, and keeping the low back flat on the wall ensures some form of pelvic control, all while in the standing position.

Based upon the advantages of hexagonal bar deadlifts (reduced lower back loads, bar closer to midline of body) and the PRI focused techniques (improving trunk and spine posture), we believe that implementing PRI promoted technique for the deadlift using the hexagonal bar will minimize the muscular activation of the back extensors. In addition, implementing a PRI technique should increase activation of the hamstrings, obliques and glutes, which should reduce the necessity of recruiting lower back musculature. Achieving neutrality in the lifters trunk/pelvis segments will ensure that the person is in an optimal position for proper respiration, and have a balanced musculoskeletal system so that there is a minimal amount of stress on joints and usage of compensatory muscular patterns (Henning et al., 2017).

CHAPTER 3 METHODS

Participants

This study was approved by the Old Dominion University Institutional Review Board (IRB #: 1373790-2). A total of sixteen young adult males and females (age 18-35 yrs.) from the Old Dominion University campus and surrounding community participated in this study. Participants were randomly chosen to be in either the intervention or the control group. Groups were matched for age and mass. Participant inclusionary criteria were: between 18 and 35 years of age, at least 1 years' experience deadlifting, and performed deadlift exercises at least once per week. Exclusionary criteria included any: self-reported history of previous surgeries to the musculoskeletal structures in either limb of the lower extremity, a history of a fracture in either limb of the lower extremity requiring realignment, and acute injury to musculoskeletal structures of other joints of the lower extremity in the previous 6 months, which impacted joint integrity and function (ie, sprains, fractures) resulting in at least 1 interrupted day of desired physical activity. Consent was obtained for all participants using approved documentation.

Experimental Protocol

All participants completed a 5-minute warm-up in preparation for deadlifting. Warmups included anything the participant needed to get ready to deadlift. After the warm up, a 16-channel wireless EMG system (2000 Hz, Deslsys Trigno, Delsys Inc.), a 10-camera motion capture system (Vicon Vantage, 200 Hz), and two force platforms (Bertec FP4060, 2000 Hz) were utilized to track participants' muscle activation, foot movements, and forces applied to their feet during deadlift exercises. Passive electrodes were placed bilaterally on participants' erector spinae, internal and external obliques, sternocleidomastoid, gluteus maximus, long head of the biceps femoris (BFLH), and semitendinosus (ST), according to SENIAM standards. The obliques and sternocleidomastoid musculature were included due to their involvement in proper forceful exhalation (Ito et al. 2016) and improper inhalation (Jung and Kim, 2016), respectively. The skin above each muscle belly was prepared by shaving hair, abrading, and cleaning the skin with alcohol wipes. Maximum muscle activation for maximal voluntary isometric contractions (MVIC) was then performed for each muscle. The procedures for the MVIC trials are detailed below. For quadricep testing, participants performed a seated leg extension with the knee at 60°. Hamstring testing was performed prone, with the knee flexed to 30°. Gluteus maximus involved a prone maximal straight leg raise. Back extensors were tested with prone back extension; the participant was instructed to lifting the trunk as high off the table as possible against the practitioner's applied resistance. Lastly, oblique testing was performed while standing, and involved trunk rotation to the right and left while pulling against a strap secured to the wall. Next, anatomical markers were placed bilaterally on the malleoli and metatarsal heads. Tracking markers were placed on the heels of the foot to track foot segment movements during dynamic trials. The participants then performed hexagonal deadlifts for 1 set of 3 repetitions at two different resistances: at 50% and at 80% of their self-reported max. Participants were provided a 5-minute rest between the two sets. No cues or coaching (words of affirmation/correction) will be provided during or between these sets. All participants were then retested using the same procedures after 15 minutes. The control group had no intervention, but participants were allowed to stretch/rest during the 15-minute period.

The intervention group was guided through a short PRI routine. The PRI routine consisted of the paraspinal release with hamstrings (Figure 2) and standing wall supported resisted reach (SWSRR; Figure 3). The paraspinal release with hamstrings was performed using the following methods. First, participants placed their hands on a box about 12 inches off the ground. The subject then placed their feet out in front of them so that the knee was at a 90° angle. Participants were then instructed to 1) dig their heels into the ground and activate the hamstrings, 2) exhale their ribs down so they have a rounded back and engaged abdominals and 3) while holding this position, perform a 3-second inhale through the nose followed by an immediate 6-second forceful exhale through the mouth, 4) pause for 2 seconds without air, and 5) then breathe normally while kicking their right leg out 5 times, all while maintaining the same position and keeping the left hamstring engaged, 6) participants will then kick their left leg out 5 times, while keeping the right hamstring engaged, 7) the participants will rest and then repeat. Participants performed a total 4 sets of 5 repetitions. The SWSRR consisted of the participants 1) placing a ball between their knees and slightly squatting down and wrapping a resistance band around back, 2) tilting the pelvis posteriorly so the lower back is flat on the wall, 3) reaching out with their arms in front of them and inhaling and exhaling the ribs down, 4) while holding this position, perform a 3-second inhale through the nose followed by an immediate 6-second forceful exhale through the mouth, 4) pause for 2 seconds without air, and 5) return to the starting posture after 5 breath cycles have been completed. Participants will perform a total 5 breaths per set for a total of 4 sets.

After the movement interventions, participants were then coached to implement PRI principles during 1 sub-maximal (50% of 1-rep max) deadlift. The participants were instructed to grab the bar, shift their weight posteriorly to the heels and engage the big toes, and then exhale through their mouth to drop the ribcage. Once the ribcage is set, learned during the PRI exercises, participants inhaled through the nose and exhaled again through the rep to keep the ribcage down and back. The participants were encouraged to feel the hamstrings and glutes activate once the ribcage was set into position. After the rep, the participants were instructed to inhale through the nose, exhale through the mouth and drop the ribcage to help reposition if they had lost the ZOA. Lastly, after this one sub-maximal repetition, participants repeated the deadlift sets without any coach or words of affirmation/correction.

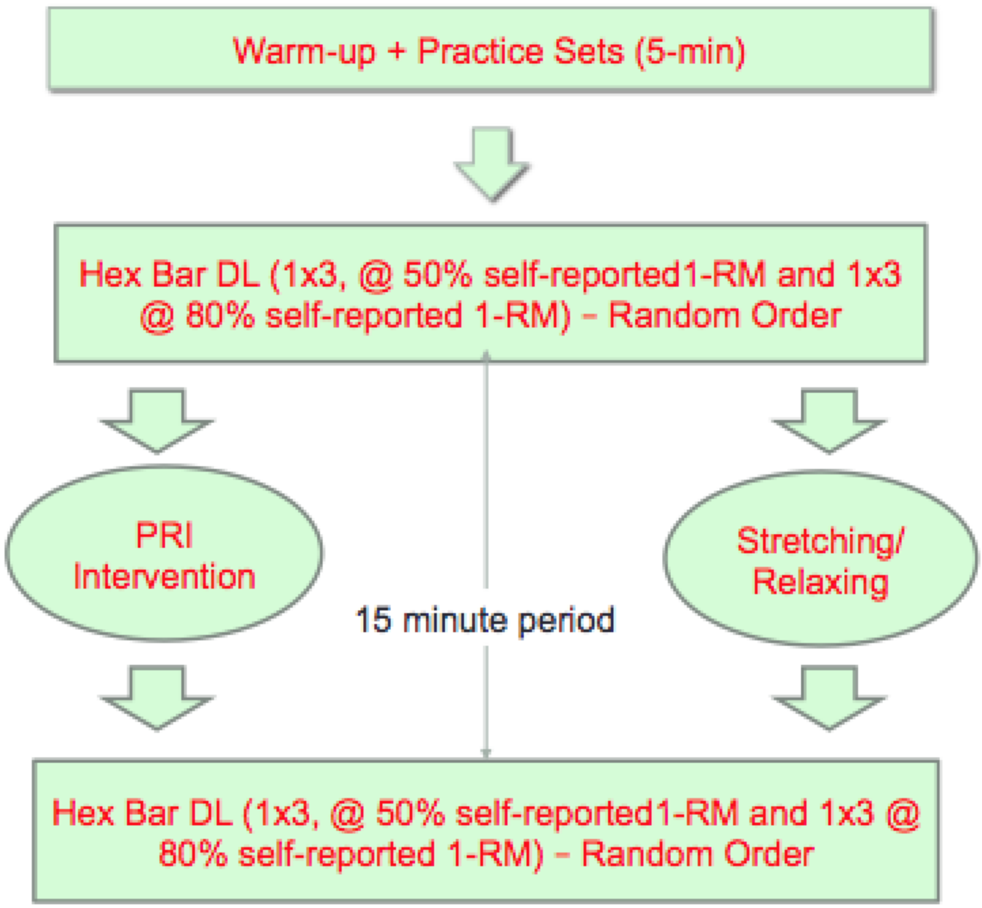

Figure 1. Flow Chart of Experimental Protocol.

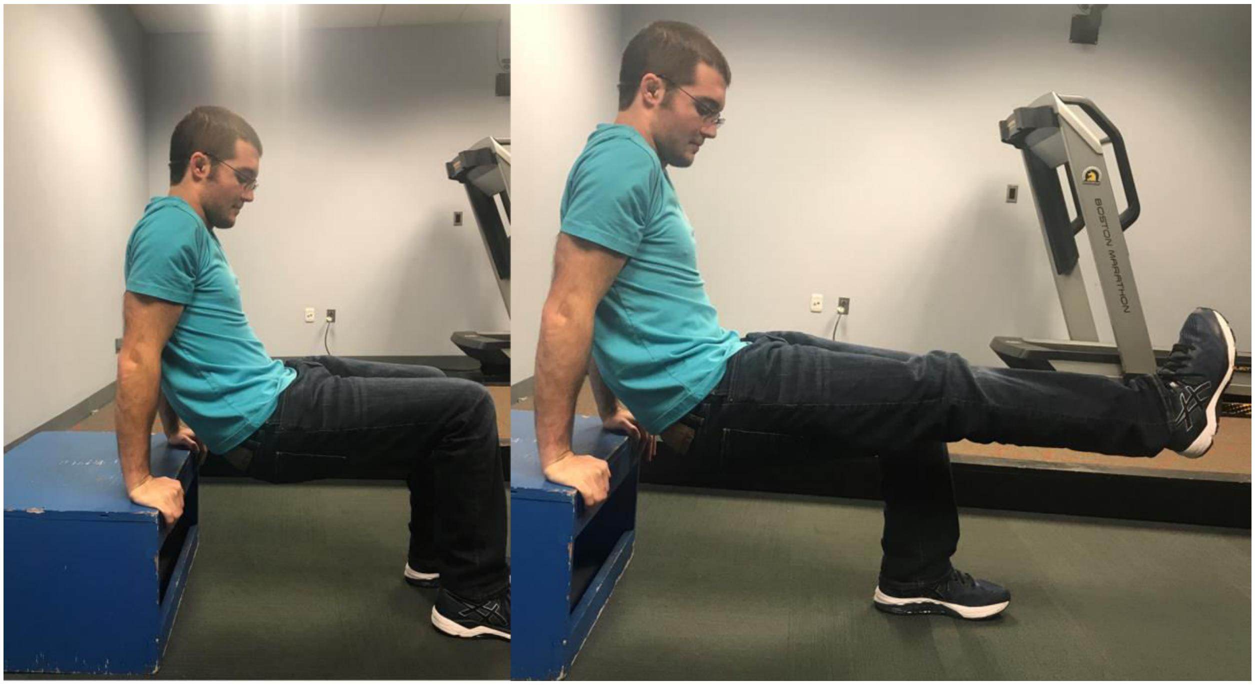

Figure 2. Paraspinal release with hamstrings exercise. See text for explanation of exercise techniques.

Figure 3. Standing wall supported resisted reach exercise. See text for explanation of exercise techniques.

Data Analysis

Motion capture and ground reaction force (GRF) data were imported into Visual3d Biomechanical Software Suite (Version 5, C-Motion, Inc.) and filtered using a zero-lag, double pass, fourth order butterworth lowpass with a cutoff frequency set at 5 Hz. Left and right foot segments were created using the malleoli and metatarsal head markers and tracked during deadlifts using markers placed on the heels. The GRF center of pressures calculated from the force plate data were transformed from the global (lab) coordinate system into the foot coordinate system. Muscle activations were high-pass filtered at 10 Hz, rectified, and low pass filtered at 5 Hz (De Luca et al., 2010). Muscle activations during dynamic trials were normalized to MVIC data.

Integrated muscle activations (iEMG), GRF waveforms, and center of pressure waveforms during the concentric portion of the deadlift were obtained.

Statistical Analysis

Normality of the discrete variables were assessed using Shapiro-Wilk tests. When the test statistic was less than 0.90, variables were transformed using the common logarithm function. A two-way analysis of variance (2 groups x 2 conditions) was utilized to determine any interaction or main effects of iEMG among the pre-intervention deadlift, post-intervention deadlift, and the two control group assessments. Significance levels were set at 0.05 apriori. Significance levels reached and effect sizes were determined for any significant iEMG tests. Group x condition mean and 95% confidence intervals were created for each GRF and center of pressure component (i..e. 3 axes). Group x condition graphs were then combined for assessing waveforms, where any non-overlapping points of the waveforms between groups/conditions indicated statistical significance.

CHAPTER 4 RESULTS

Group Anthropometrics

Anthropometric data are provided in Table 1. Groups were not different in age, mass, or height (all $p<0.05$).

Table 1: Anthropometric Data

	Intervention Group	Control Group	P-Value
Age (years)	21.13 ± 1.25	23.25 ± 3.85	0.64
Height (meters)	1.76 ± 0.9	1.72 ± 0.08	0.37
Weight (kilograms)	79.48 ± 12.12	76.6 ± 11.99	0.17

Note: Eight participants per group.

Muscle Activations

There were no significant interactions or group/condition main effects for any of the tested muscles (Tables 2 & 3). Waveforms of ensemble muscle activations during the concentric phase are provided in Figures 4-10.

Table 2: Lower Extremity Muscle iEMG Comparisons: mean±std.

	Intervention Group		Control Group	
	Pre	Post	Pre	Post
Biceps Femoris	.308 ± .253	.273 ± .249	.355 ± .307	.358 ± .344
Semitendinosus	.256 ± .135	.249 ± .154	.269 ± .165	.277 ± .164
Rectus Femoris	2.19 ± 4.30	1.84 ± 2.81	1.72 ± 3.17	1.51 ± 2.94
Gluteus Maximus	.396 ± .170	.363 ± .141	.472 ± .674	.534 ± .778

Note: Pre: activations during deadlifts prior to PRI intervention; Post: activations after PRI intervention.

Table 3: Trunk Muscle iEMG Comparisons: mean±std.

	Intervention Group		Control Group	
	Pre	Post	Pre	Post
Back Extensors	.809 ± .756	.786 ± .757	.774 ± .698	.732 ± .498
External Obliques	.126 ± .173	.350 ± .719	.176 ± .232	.178 ± .199
Internal Obliques	.626 ± 1.23	.443 ± .526	.774 ± .698	.732 ± .498

Note: Pre: activations during deadlifts prior to PRI intervention; Post: activations after PRI intervention.

Figure 4: Back Extensors Activations during the Concentric Phase of Deadlifting.

Muscle activation (% MVIC) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

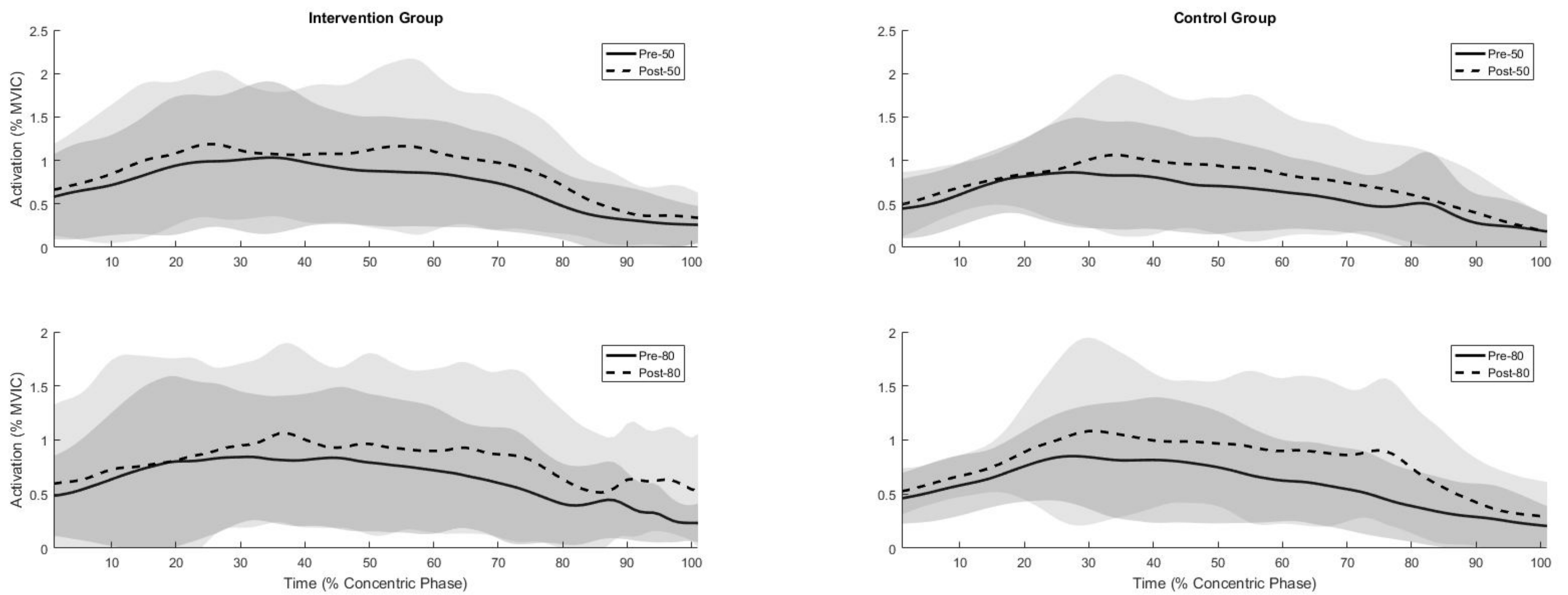

Figure 4 Caption: Columns one and two present muscle activations for the Intervention and Control group, respectively. Rows one and two present activations during deadlifts with 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 5: Biceps Femoris Activations during the Concentric Phase of Deadlifting.

Muscle activation (% MVIC) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

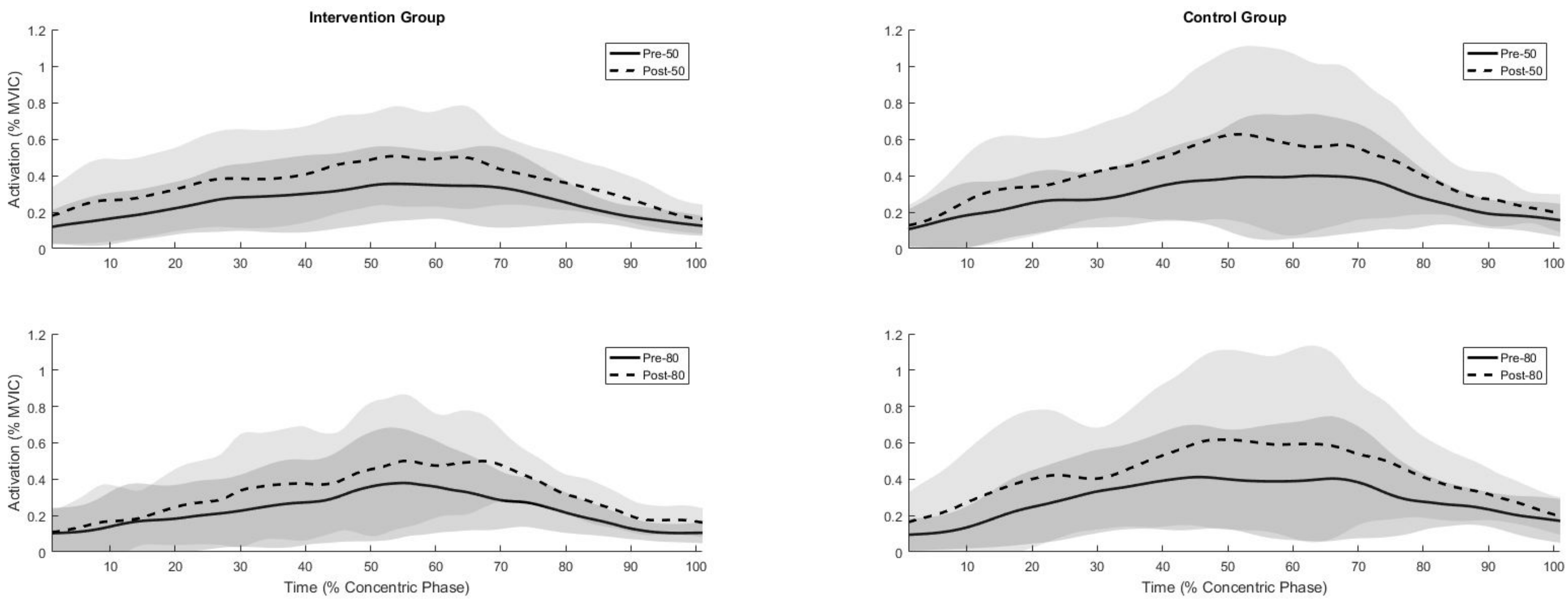

Figure 5 Caption: Columns one and two present muscle activations for the Intervention and Control group, respectively. Rows one and two present activations during deadlifts with 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 6: External Obliques Activations during the Concentric Phase of Deadlifting.

Muscle activation (% MVIC) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

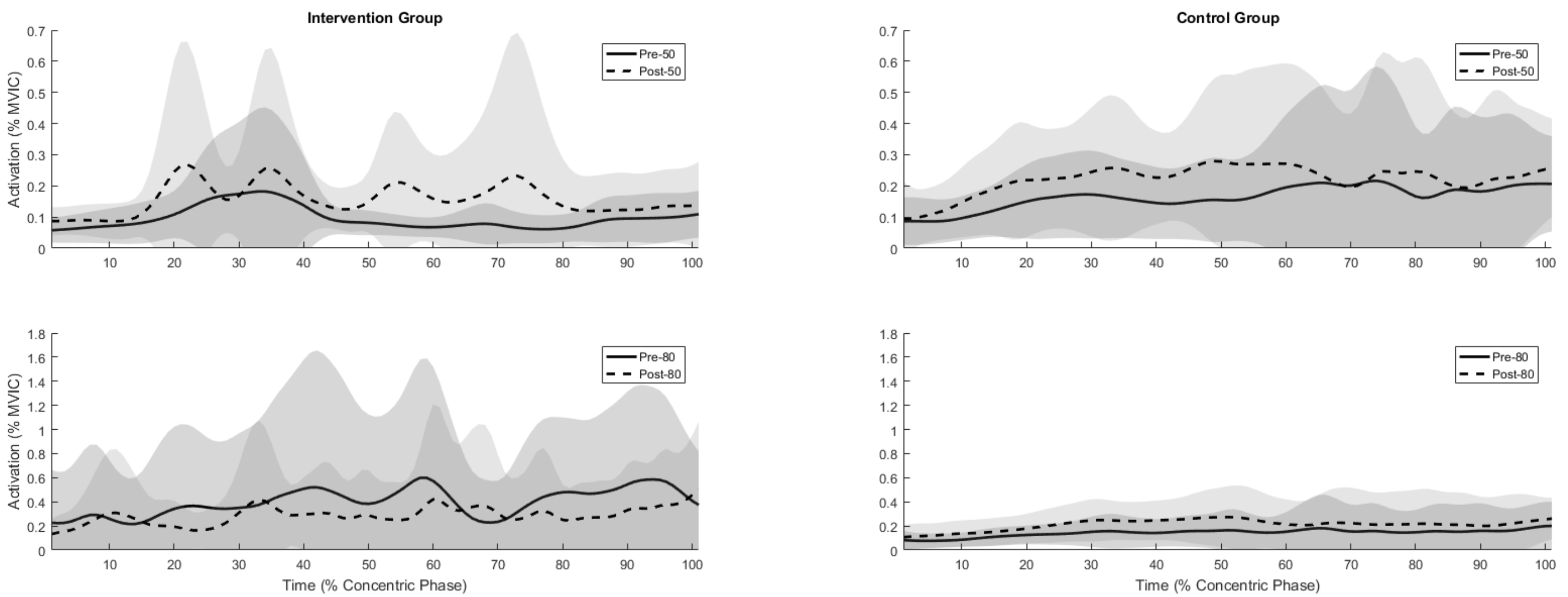

Figure 6 Caption: Columns one and two present muscle activations for the Intervention and Control group, respectively. Rows one and two present activations during deadlifts with 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 7: Gluteus Maximus Activations during the Concentric Phase of Deadlifting.

Muscle activation (% MVIC) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

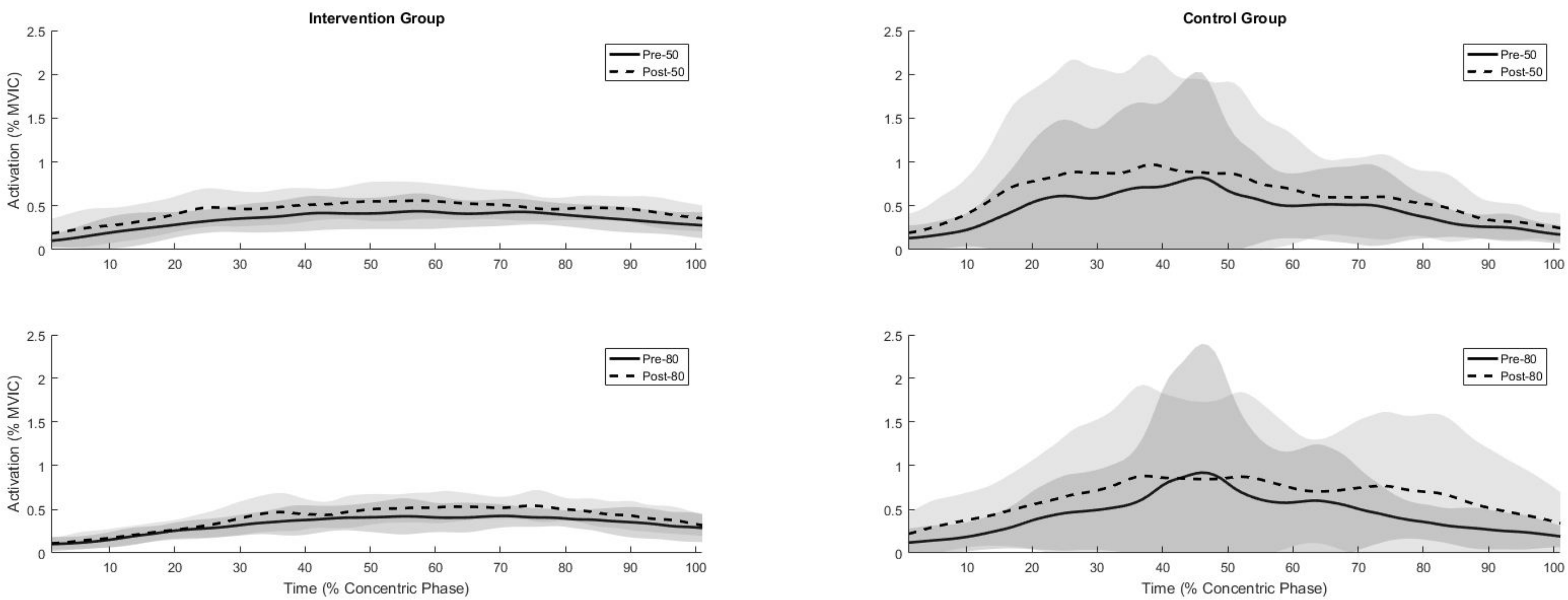

Figure 7 Caption: Columns one and two present muscle activations for the Intervention and Control group, respectively. Rows one and two present activations during deadlifts with 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 8: Internal Obliques Activations during the Concentric Phase of Deadlifting.

Muscle activation (% MVIC) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

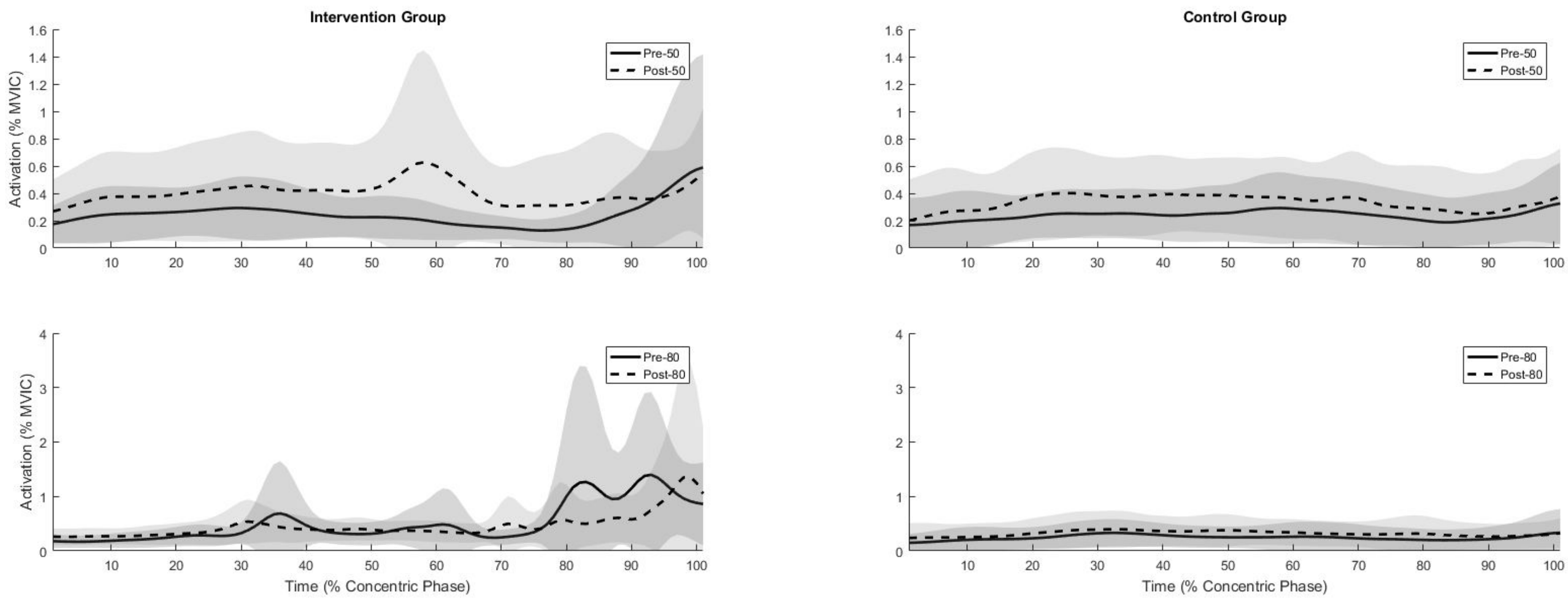

Figure 8 Caption: Columns one and two present muscle activations for the Intervention and Control group, respectively. Rows one and two present activations during deadlifts with 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 9: Rectus Femoris Activations during the Concentric Phase of Deadlifting.

Muscle activation (% MVIC) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

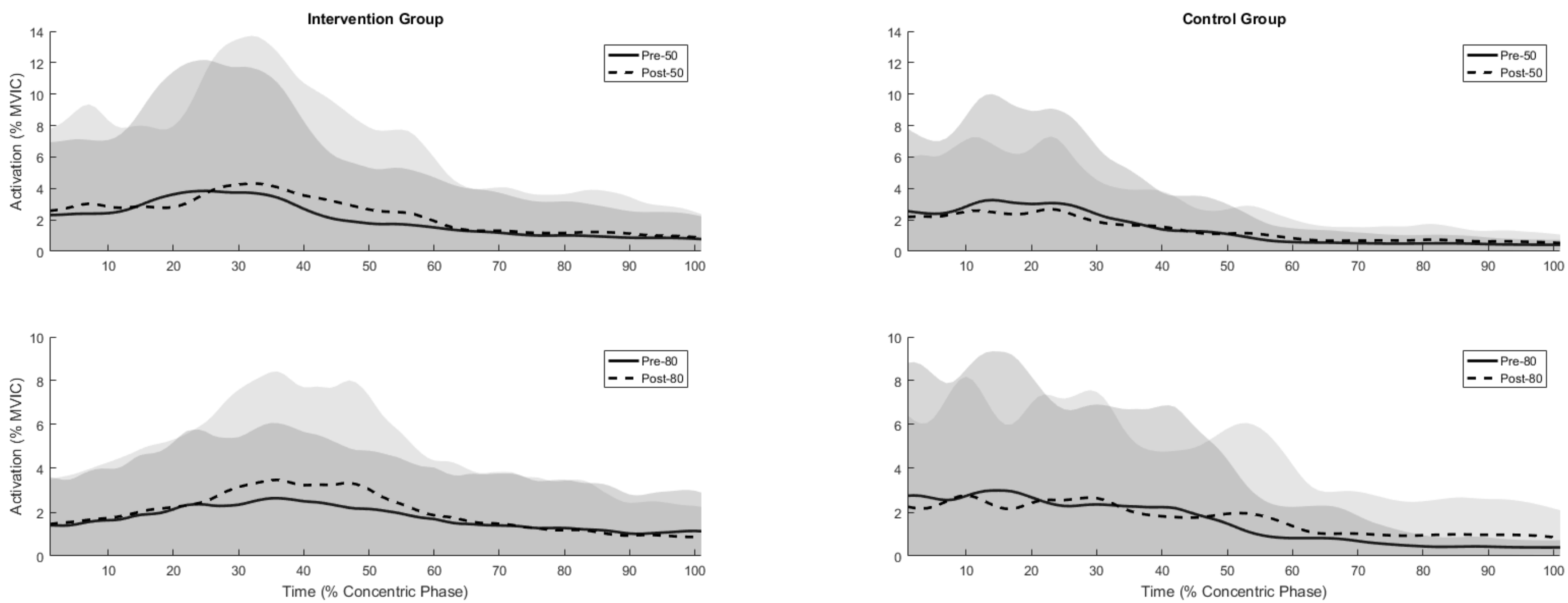

Figure 9 Caption: Columns one and two present muscle activations for the Intervention and Control group, respectively. Rows one and two present activations during deadlifts with 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 10: Semitendinosus Activations during the Concentric Phase of Deadlifting.

Muscle activation (% MVIC) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

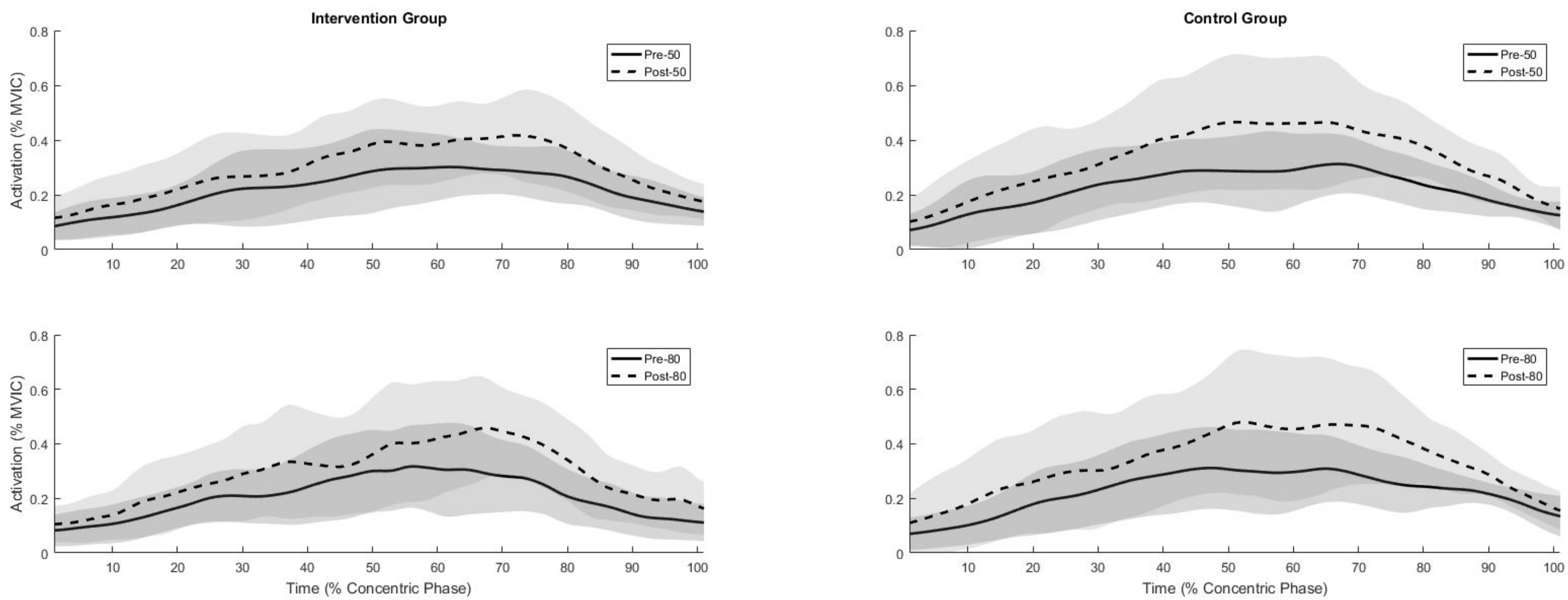

Figure 10 Caption: Columns one and two present muscle activations for the Intervention and Control group, respectively. Rows one and two present activations during deadlifts with 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

GRF Center of Pressures

Waveforms of the GRF and center of pressure data are provided in Figures 11-20. There was a significant difference in the anteroposterior center of pressure for the right foot pre and post intervention with a 50% 1-rep max load. For the first 25% of the concentric phase, the center of pressure on the right foot shifted posteriorly post-intervention compared to pre-intervention ($p<0.05$). No other significant differences were found.

Figure 11: Left Foot Anterior/Posterior Center of Pressure.

Anteroposterior COP (m) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

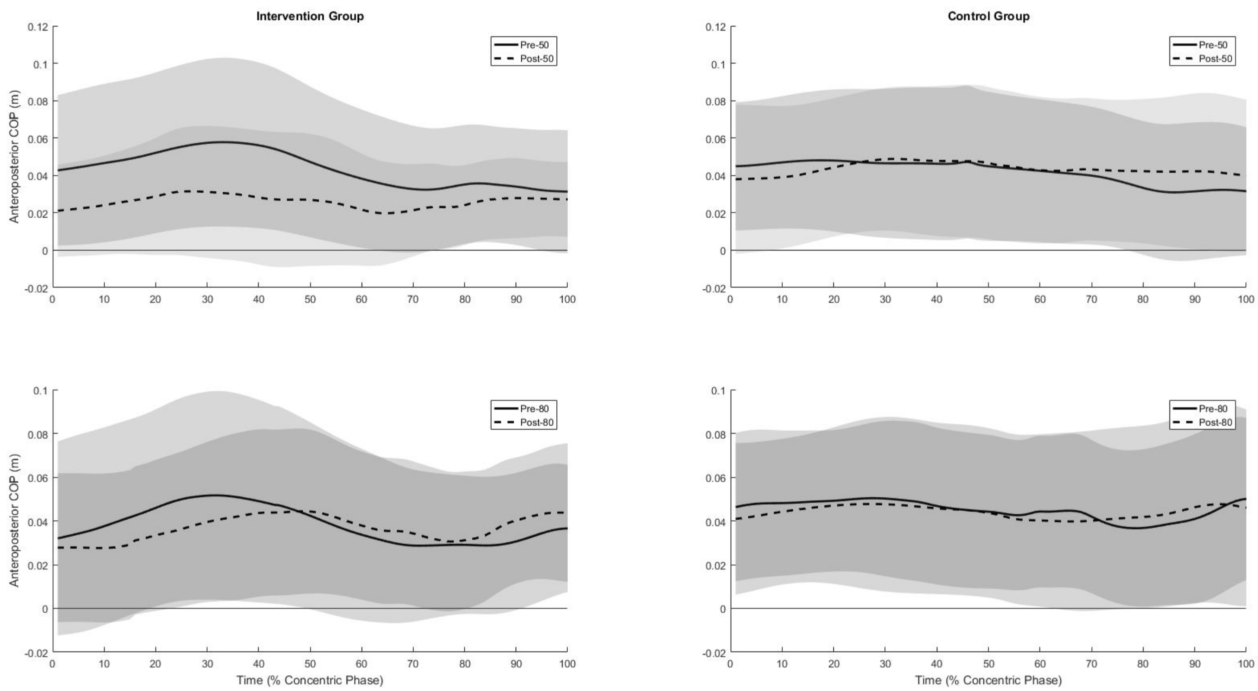

Figure 11 Caption: Columns one and two present left foot anterior/posterior center of pressures for the Intervention and Control Group. Rows one and two present left foot anterior/posterior center of pressures during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 12: Left Foot Anterior/Posterior Ground Reaction Forces.

Anteroposterior GRF (N) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

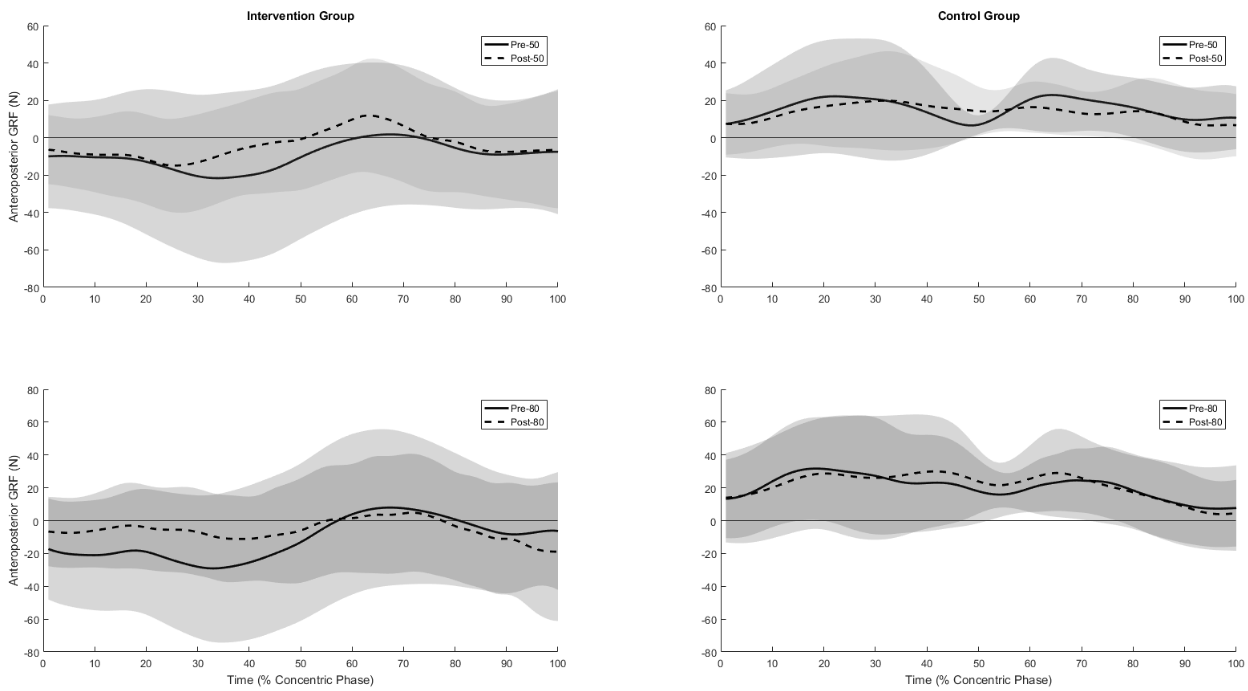

Figure 12 Caption: Columns one and two present left foot anterior/posterior ground reaction forces for the Intervention and Control Group. Rows one and two present left foot anterior/posterior ground reaction forces during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 13: Left Foot Medial/Lateral Center of Pressure.

Mediolateral COP (m) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

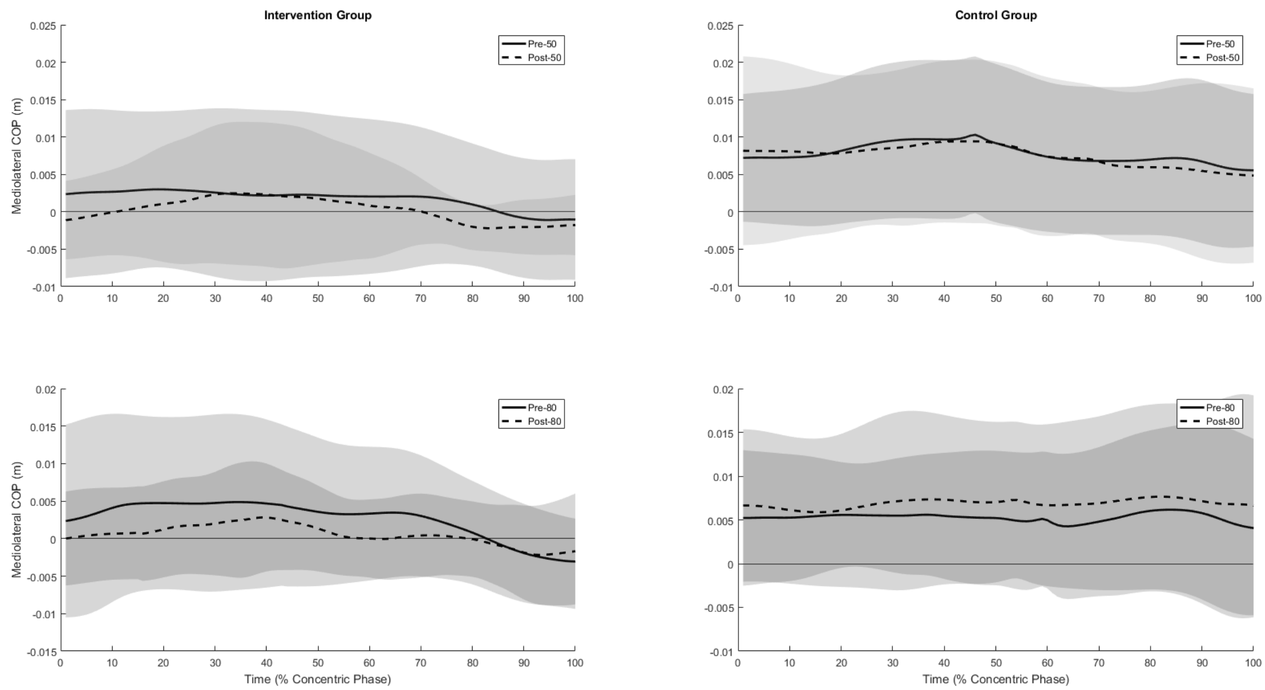

Figure 13 Caption: Columns one and two present left foot medial/lateral center of pressures for the Intervention and Control Group. Rows one and two present left foot medial/lateral center of pressures during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 1: Left Foot Medial/Lateral Ground Reaction Forces.

Mediolateral GRF (N) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

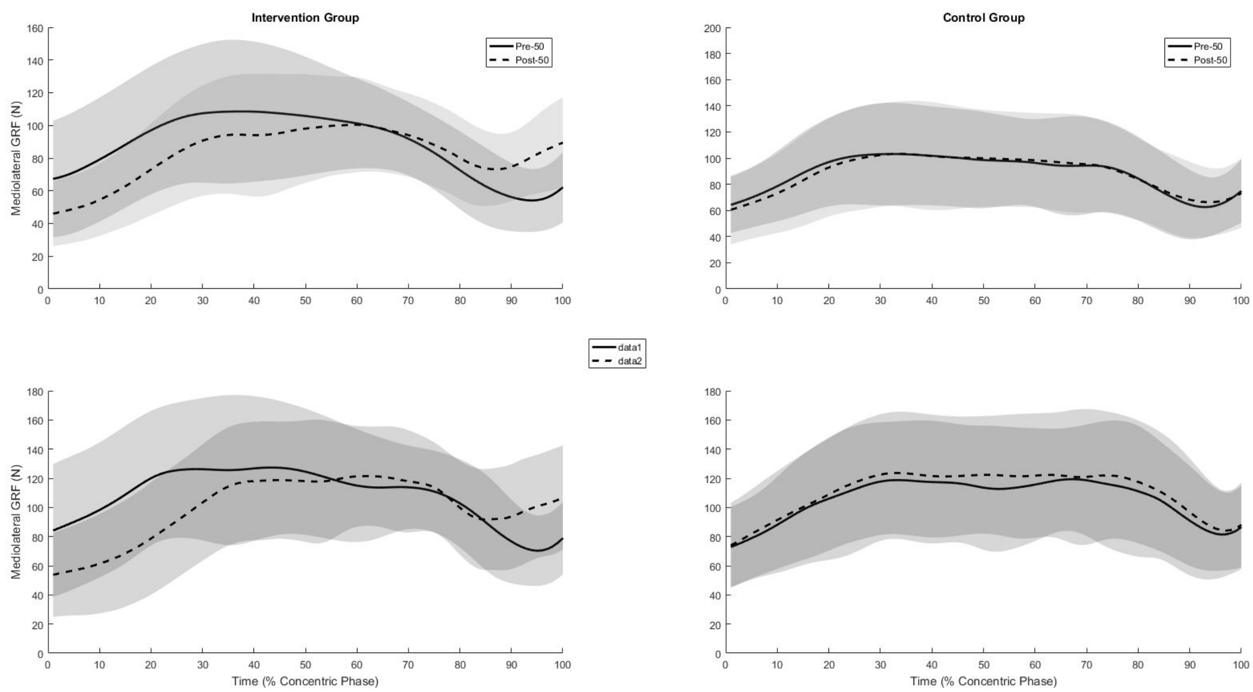

Figure 14 Caption: Columns one and two present left foot medial/lateral ground reaction forces for the Intervention and Control Group. Rows one and two present left foot medial/lateral ground reaction forces during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 2: Left Foot Vertical Ground Reaction Forces.

Vertical GRF (N) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No signficant differences were found.

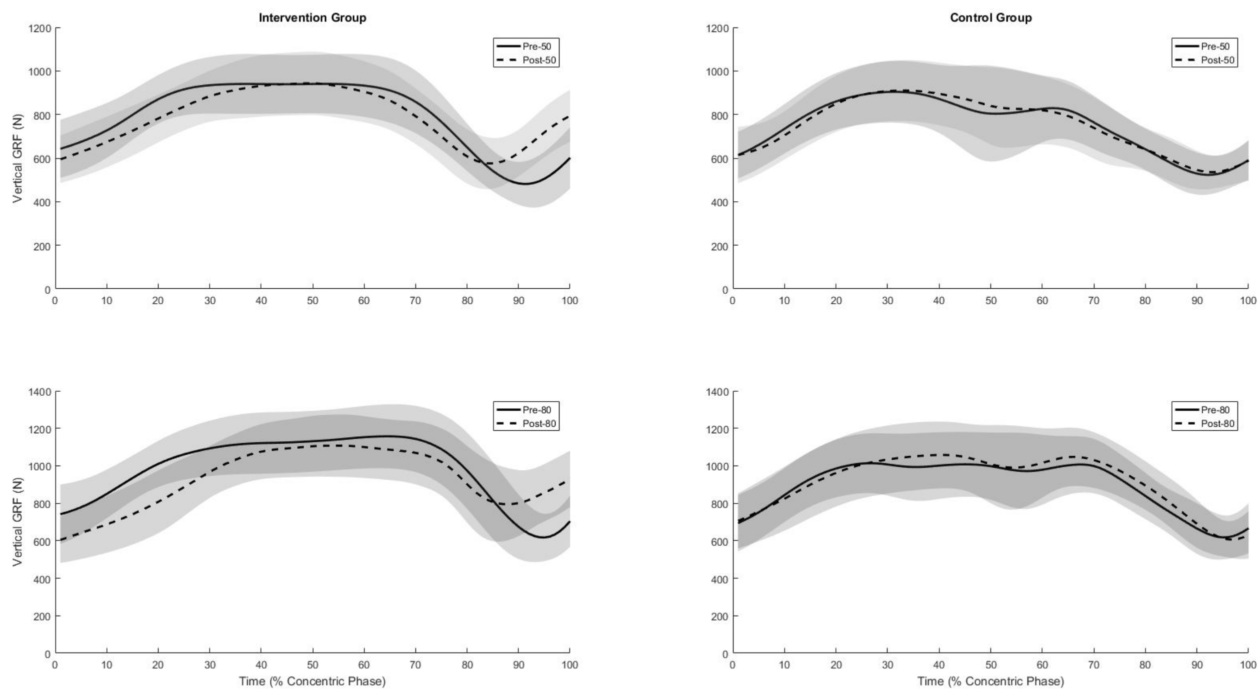

Figure 15 Caption: Columns one and two left foot vertical ground reaction forces for the Intervention and Control Group. Rows one and two present left foot vertical ground reaction forces during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 3: Right Foot Anterior/Posterior Center of Pressure.

Anteroposterior COP (m) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). For the first 25% of the concentric phase, the center of pressure on the right foot shifted posteriorly post-intervention compared to pre-intervention ($p<0.05$).

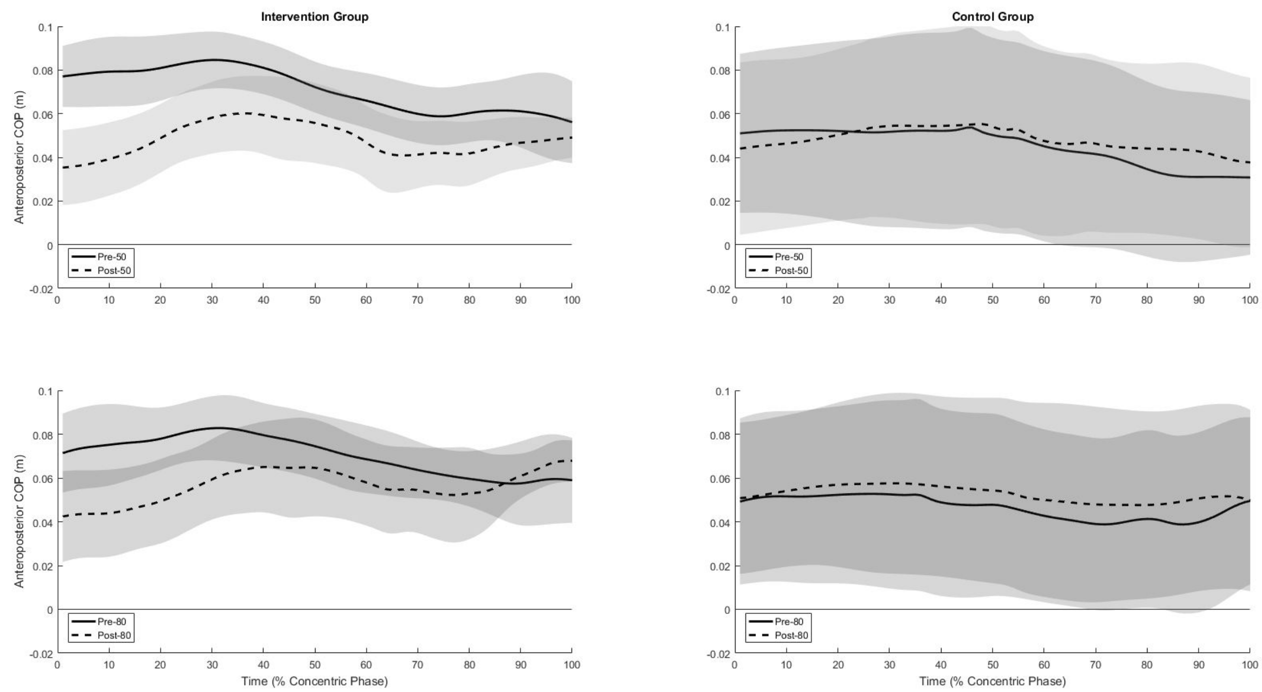

Figure 16 Caption: Columns one and two present right foot anterior/posterior center of pressures for the Intervention and Control Group. Rows one and two present right foot anterior/posterior center of pressures during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 4: Right Foot Anterior/Posterior Ground Reaction Forces.

Anteroposterior GRF (N) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No significant differences were found.

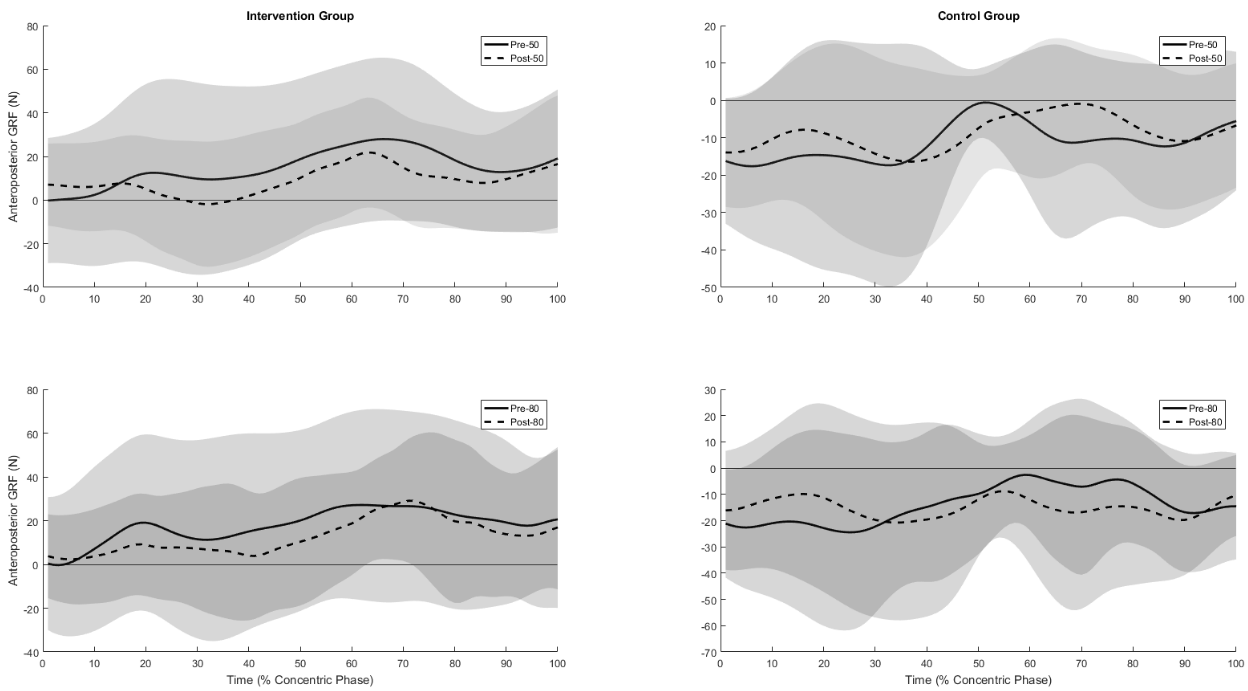

Figure 17 Caption: Columns one and two present right foot anterior/posterior ground reaction forces for the Intervention and Control Group. Rows one and two present right foot anterior/posterior ground reaction forces during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 5: Right Foot Medial/Lateral Center of Pressure.

Mediolateral COP (m) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No significant differences were found.

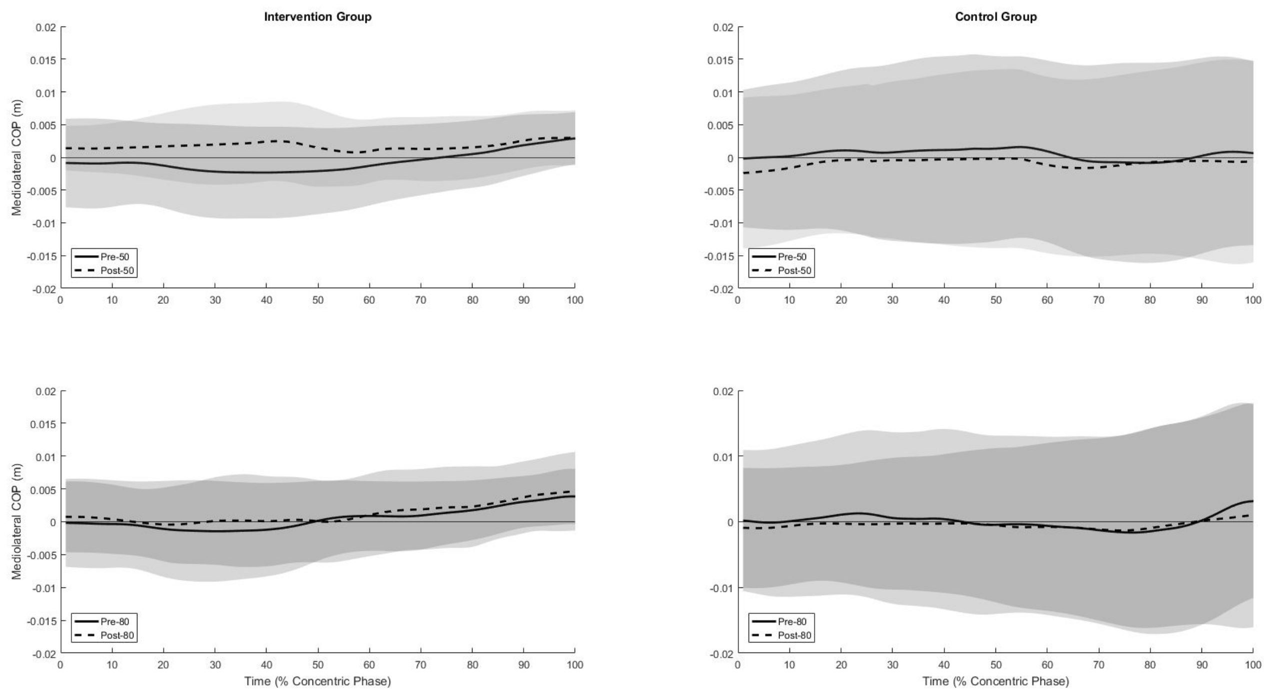

Figure 18 Caption: Columns one and two present right foot medial/lateral center of pressures for the Intervention and Control Group. Rows one and two present right foot medial/lateral center of pressures during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 6: Right Foot Medial/Lateral Ground Reaction Forces.

Mediolateral GRF (N) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No significant differences were found.

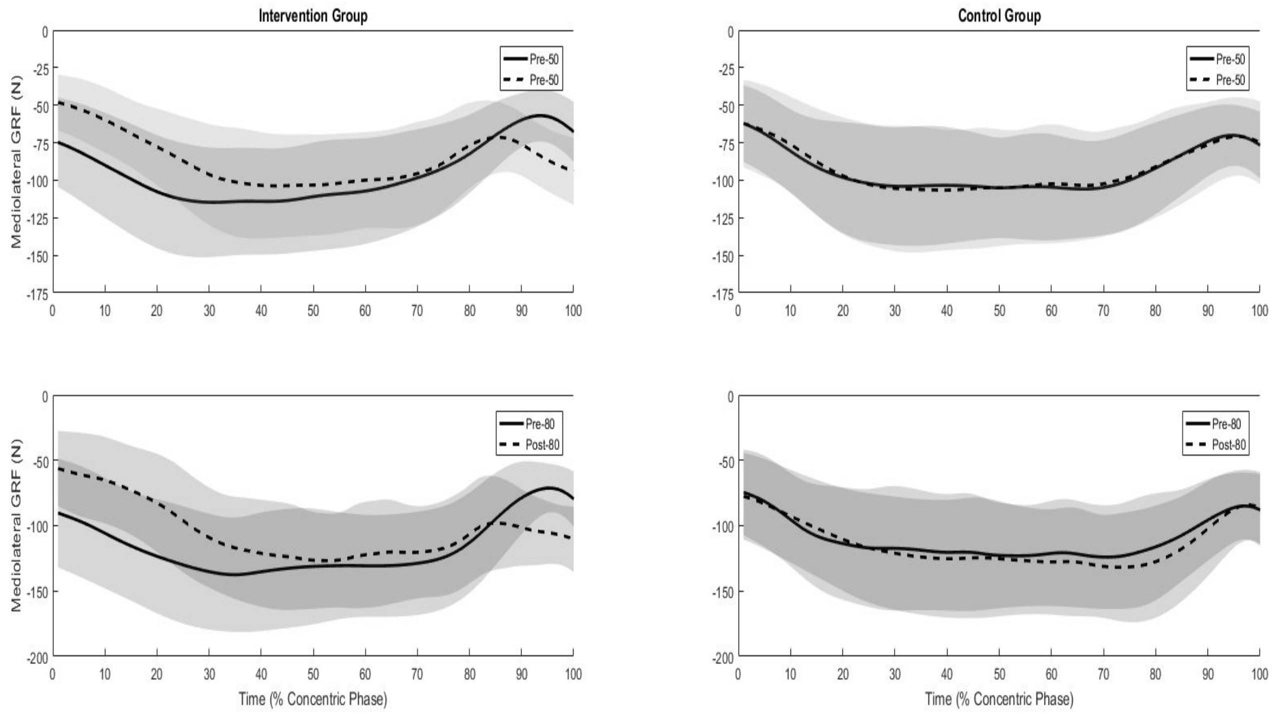

Figure 19 Caption: Columns one and two present right foot medial/lateral ground reaction forces for the Intervention and Control Group. Rows one and two present right foot medial/lateral ground reaction forces during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark gray shadings: Post-Intervention mean and one standard deviation.

Figure 20: Right Foot Vertical Ground Reaction Forces.

Vertical GRF (N) vs. time (% concentric phase of deadlift) for the intervention group (pre-50% vs post-50%, and pre-80% vs post-80%), and for the control group (pre-50% vs post-50%, and pre-80% vs post-80%). No significant differences were found.

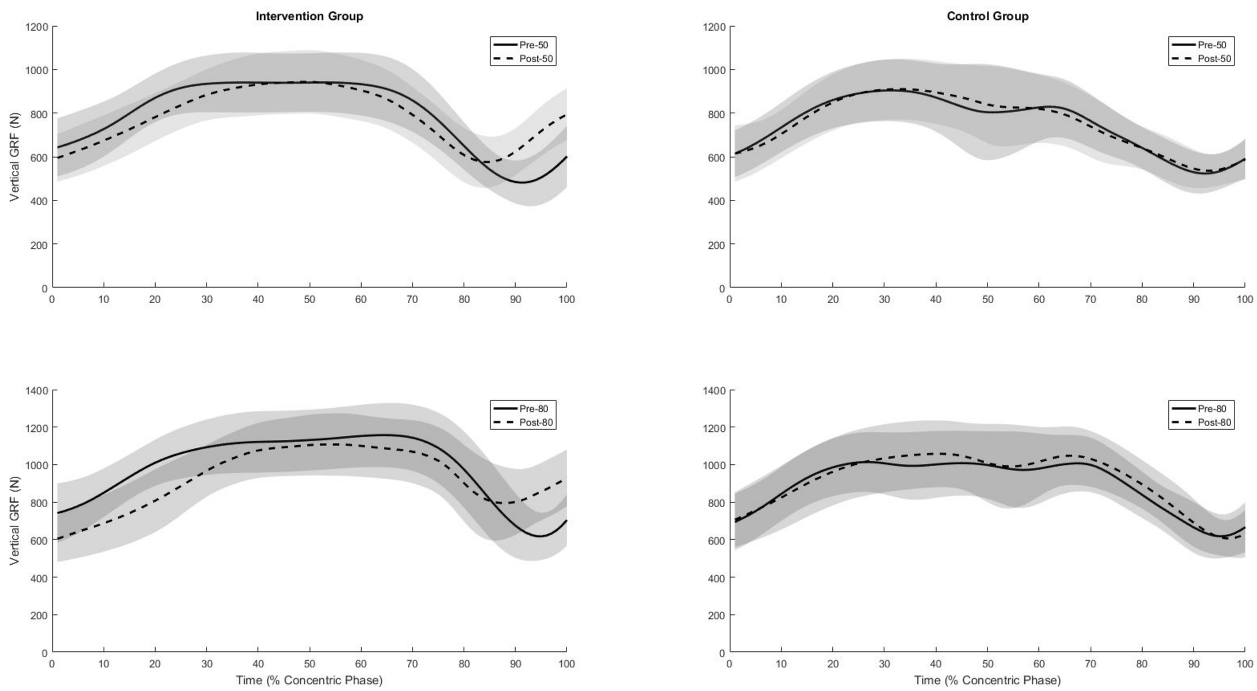

Figure 20 Caption: Columns one and two right foot vertical ground reaction forces for the Intervention and Control Group. Rows one and two present right foot vertical ground reaction forces during deadlifts at 50% and 80% resistances, respectively. Solid lines and light gray shadings: Pre-Intervention mean and one standard deviation. Dashed lines and dark grey shadings: Post-Intervention mean and one standard deviation.

CHAPTER 5 DISCUSSION

The purpose of this study was to determine the efficacy of implementing two Postural Restoration exercises and relating principles on deadlifts using a hexagonal barbell. We hypothesized that the PRI intervention would increase hamstring, oblique and glute activation, reduce lumbar extensor activation, and result in GRF center of pressure moving more posteriorly to the heels during the deadlift. Overall, our hypotheses were not supported as there were no significant EMG or center of pressure differences between groups (intervention vs. controls) or pre/post intervention.

We examined muscle activation of bilateral back extensors, gluteus maximus, hamstrings (biceps femoris long head and semitendinosus), obliques, and quadriceps (rectus femoris) at 50% and 80% of an estimated 1-RM. We found no significant difference for the intervention group for the back extensors, glute, hamstring or oblique activation during the concentric portion of deadlifts with a hexagonal bar. The PRI approach recommends the hexagonal bar over the conventional bar, as the load remains closer to the COG, requiring less back extension during the movement (*PRI Integration for Fitness and Movement Course,* 2016). Additionally, increasing hamstring and abdominal activation are core components of PRI's methodology, which should help deactivate hip flexors and overactive back extensors (Tenney et al., 2013). Interestingly, the hexagonal bar deadlift was found to be a more quadriceps-dominant movement, with significantly greater EMG vastus lateralis activation during the concentric and eccentric portions of the deadlift for a hexagonal bar vs. a conventional bar (Camara et al., 2016). The same study by Camara et al., 2016, found that the erector spinae were significantly more active during the eccentric portion of the straight bar deadlift when compared to the hexagonal bar; however, the EMG results were not significantly different during the concentric portion. We theorized that the form used during the exercise is more important than the exercise choice itself. This is why we hypothesized combining the PRI activities with form coaching would result in a muscle activation change during the deadlift. Again, we did not find any significant muscle activation changes due to the short-term non-manual PRI intervention.

The PRI activities implemented in this study target increasing hamstring and oblique activations. When applied to the hexagonal bar deadlift, the PRI activities involve first instructing participants to pull through their heels by bringing their weight back to posteriorly shift the pelvis (The amount of shifting and tilting depended on the participant, no participants were encouraged to lift from a posterior tucked, flexed position, but from a neutral pelvis). The posterior pelvic shift should result in increased glute and hamstring activation, per PRI assumptions. Next, participants were instructed to perform a forceful exhale to translate and lower the ribcage. Both of these steps were instructed to be performed prior to the concentric phase of the lift. One possible reason for the lack of results in our study could be due to the short intervention time given the complexities of the proposed changes to participants' deadlifting form. We implemented this short intervention because studies show that PRI can elicit changes in ADT, which would indicate repositioning of the pelvic region, in one session (Tenney et al., 2013). Furthermore, PRI has shown the ability to increase respiration volume by restoring optimal ZOA, which would indicate a change in ribcage position in relation to the pelvis (Boyle, 2010). However, learning a new deadlift form on top of the PRI exercises may have been too complex. In a traditional therapy and strength coaching setting, many of the participants would not be progressed to deadlifting for multiple sessions after learning Postural Restoration movement patterns and principles. The weight would also be decreased when learning to deadlift in this new position. Often times during the deadlift post-intervention, the subject set up properly but would revert back to their old deadlift pattern to get the weight up. Another possibility is the lack of a bilateral hamstring exercise, since the hexagonal bar deadlift is a bilateral exercise itself. However, it is pertinent that research, such as the current work, evaluate claims by rehabilitation programs using both short and long term forms of their prescribed interventions to provide assessments of validity. Future work should address longer term implementations of PRI interventions on deadlifting.

PRI recommends that the patients be able to "sense and feel their left heel and right arch" (Postural Respiration Course, 2019). These reference centers allow patients to inhibit the L AIC chain of muscles, which would consist of getting the left leg out of a constant swing phase of gait, requiring more hamstring and less quadriceps and hip flexors. The right arch helps activate the right glute max, which helps the patient get over to the left and stay in left stance for the proper amount of time. In general, sensing both heels is necessary to help get the patient out of a bilateral anterior pelvic tilt, which is commonly seen in the PEC patient (*PRI Integration for Fitness and Movement Course,* 2016). The coaching in this study consisted of the participants finding their heels, regardless of left and right side. This was done because the deadlift is a bilateral exercise. However, no significant changes were seen in the center of pressure or the GRF waveform results, other than the anteroposterior center of pressure for the right foot pre and post intervention with a 50% 1-rep max load, which was only for the first 25% of the concentric phase. This was simply not enough of a change, and only from 50% of 1-rep max, to draw any substantial conclusions from. In addition to the bilateral nature of the exercise, we did not aim to assess the PRI patterns each participant exhibited (which would generally indicate which specific muscles need inhibition and activation). Again, the lack of significant results may be that the participants just did not have enough time to change and maintain the desired body position under load. We know that PRI can elicit changes in one session because of the neuromuscular nature (Boyle, 2013), but perhaps this was too much motor learning to occur in a short amount of time. The lack of footwear may have also presented some issues with the participants finding their heels and maintaining that posture, since PRI recommends certain shoes to help with the grounding process (https://www.hruskaclinic.com/shoe-list.html). However, a study by Hammer et al., 2018, found no significant difference in anterior-posterior center of pressure during the deadlift when comparing shod vs. unshod. The previous study did find a significant difference in medial-lateral center of pressure with shod vs. unshod (23.3mm vs. 18.6mm @ 80%). Given the effect of wearing shoes during deadlifts for mediolateral center of pressures, future work should also consider including multiple footwear conditions.

Practical Applications

Despite the lack of significant results, valuable insight can be gained from this study, especially from a strength and conditioning practitioner's point of view. First and foremost, if a coach plans to utilize a PRI-inspired methodology, it would be beneficial to work closely with a PRC to diagnose and prescribe additional treatment/intervention plans. Second, as previously mentioned, coaches will want to ensure that the client has enough experience and mastery over PRI concepts before progressing to altering deadlift mechanics. This means clients should be able to "sense" their heels, hamstrings and glutes, as well as keep proper ZOA during the concentric and eccentric portions of the deadlift. Clients should not be in excessive lumbar lordosis and be fully able to ground and push through the floor. Second, because a new position has been established, the client may be "weaker" than before from a total weight lifted perspective. This is to be expected because of the new position and mechanics during the deadlift.

Conclusion

We examined the effects of a non-manual PRI intervention on muscle activation of bilateral back extensors, gluteus maximus, hamstrings (biceps femoris long head and semitendinosus), obliques, and quadriceps (rectus femoris) during hexagonal deadlifts at 50% and 80% of an estimated 1-RM. We found no significant EMG differences for the intervention group for the back extensors, gluteus, hamstrings (biceps femoris long head and semitendinosus), or oblique activation during the hexagonal bar deadlift. Additionally, we found no significant center of pressure differences, other than the anteroposterior center of pressure waveform for the right foot pre and post intervention with a 50% 1-rep max load, which was only for the first 25% of the concentric phase. Again, this was simply not enough of a change, and it certainly does not support our hypothesis of more force production through the heels on both sides, to draw any substantial conclusions from. Based on our lack of significant findings, short-term non-manual PRI interventions and coaching does not appear to positively affect deadlift mechanics.

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