THE EFFECT OF SUSPENDED WEIGHT RESISTANCE TRAINING ON DYNAMIC BALANCE, MUSCULAR STRENGTH, MUSCULAR POWER, AND AGILITY IN COLLEGIATE ATHLETES

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ABSTRACT

Instability resistance training techniques are commonly used to increase athletic performance. The purpose of the present study was to analyze the effects of performing the squat exercise with suspended weight within a six-week resistance training program on dynamic balance, maximal strength, agility, and power in collegiate male athletes. Thirty-two male collegiate baseball players were randomly assigned to suspended (experimental) or conventional (control) training groups and completed 1RM squat, dynamic balance, vertical jump, and agility tests before and after a six-week resistance training program. The only difference between otherwise identical programs was the suspended group's use of suspended loading on the barbell in the squat exercise.

Post-test data revealed significant 1RM squat increases in the suspended (6.9%) and conventional (4.5%) groups, but no significant changes in balance. Although statistically insignificant, vertical jump changed by +2.27% and -0.70% and agility by +1.23% and +1.00% in the suspended and conventional groups, respectively.

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CHAPTER I. INTRODUCTION

Success in athletics requires a broad range of physical skills. Athletes use a variety of training techniques to enhance skills such as speed, strength, and power. Postural balance is another skill that influences athletic performance. Successful athletic performance greatly depends on the body's ability to maintain upright posture during forward, backward, and lateral movements (Yaggie & Campbell, 2006). This can be achieved through the strengthening and improved coordination of the core stabilizing muscles. The core is comprised of the abdominal, oblique, gluteal, and paraspinal muscle groups, in addition to the diaphragm, pelvic floor, and hip girdle; together these muscles surround the trunk region and support the spine (Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013; Willardson, 2007). A strong core creates a firm foundation for limb movement (Anderson & Behm, 2005; Behm & Anderson, 2006; Behm, Drinkwater, Willardson, & Cowley, 2010; Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013; Willardson, 2007).

Studies have linked greater muscle activation in the core to exercises that require greater body stabilization (Campbell, Kutz, Morgan, Fullenkamp, & Ballenger, 2014; Schwanbeck, Chilibeck, & Binsted, 2009). Unstable surface training, in particular, has been shown to increase core strength and stability beyond that which results from regular season competition, practice, and strength training (Oliver & Brezzo, 2009). Training under unstable conditions challenges the neuromuscular system in a way that replicates the demands faced while performing many sports tasks (Behm et al., 2010; Kibele & Behm, 2009; Willardson, 2007). Because of this, many athletes are beginning to implement balance training and instability resistance training (IRT) techniques in addition to traditional resistance training geared toward speed, strength, and power development in order to improve their ability to react to the dynamic movements and variable forces experienced in most athletic environments (Yaggie & Campbell, 2006).

Despite the core strength and stability benefits, however, IRT may not be as effective at muscular strength and power development in the limb musculature. Improving these areas requires an athlete to generate near maximal muscular force in their training. Research shows that exercise under unstable conditions tends to result in reduced muscular force production (Anderson & Behm, 2004; Behm, Anderson, & Curnew, 2002; Cotterman, Darby, & Skelly, 2005; Cressey, West, Tiberio, Kraemer, & Maresh, 2007; Kohler, Flanagan, & Whiting, 2010; Koshida, Urabe, Miyashita, Iwai, and Kagimori, 2008; McBride, Cormie, & Deane, 2006). Generally, IRT requires a lighter training load because more muscle activation is used for stability rather than muscular force production (Anderson & Behm, 2004; Behm et al., 2002; Cotterman et al., 2005; Kohler et al., 2010; Koshida et al., 2008; McBride et al., 2006). The reduced load is insufficient to produce strength improvement because near maximal muscular force is not being achieved (Cressey et al., 2007).

In contrast to these findings, other studies have found no difference in strength gains between stable and unstable training programs (Kibele & Behm 2009; Sparkes & Behm, 2010). This indicates that it may be the degree of instability in an exercise that determines its ability to improve muscular strength. There is little research analyzing the effect of IRT techniques and programs on performance measures such as strength, power, agility, and balance. There is also limited research investigating IRT with unstable loads rather than an unstable surface, especially using suspended training loads rather than conventional loading on a barbell. One study has found unstable load training with suspended weight to elicit greater muscle activation in the core musculature with very minor decreases in force production (Lawrence & Carlson, 2015). The present study was designed to investigate the effect of performing the squat exercise with the weights suspended from the barbell using Spud, Inc. Stump Straps (Stump Straps; Spud, Inc., Columbia, South Carolina, USA) as part of a six-week resistance training program on muscular strength, balance, agility, and power.

The combination of balance training with resistance training is ideal as long as the level of instability is great enough to elicit improvements in balance via core stabilization, yet low enough to allow for maximal force production (Behm & Anderson, 2006). The ability to train both strength and balance simultaneously by increasing core stability would be more efficient for athletes and coaches in terms of time and energy. With athletes continually striving to maximize their performance, it is important to assess the efficiency and specificity of the training methods available to them.

Purpose of The Study

The purpose of this study was to analyze the effects of performing the squat exercise with suspended weight on dynamic balance, maximal strength, agility, and power in collegiate male athletes.

Research Questions

- Does performing the squat exercise with a suspended load elicit the same strength improvement as conventional loading in the squat exercise after a six-week resistance training program?
- Does performing the squat exercise with a suspended load elicit greater balance improvement than the conventional squat after a six-week training program?
- Does performing the squat exercise with a suspended load influence agility and power differently than the conventional squat after a six-week training program?

Significance of the Study

If balance, agility, and/or power improvements are greater in the experimental group without a reduction in maximal strength increases when compared to the standard squat control group, it may be possible that training using suspended loads is a more effective and time efficient way for athletes to train. Training using these methods may allow athletes to improve strength and balance simultaneously rather than in separate training programs. There is little published research examining the use of suspended loads during resistance training.

Limitations of the Study

- All subjects participated in an identical resistance training program with exception to the squat exercise, so this may negate any differences resulting from the experimental intervention.
- The training age of each athlete may have an effect on his strength, balance, agility, and/or improvement.
- This study only analyzed trained male athletes. Untrained individuals may respond differently. Gender may also impact training outcomes.

Delimitations of the Study

- All participants had undergone a resistance training program prior to this study and were qualified to begin maximal strength training.
- All participants had been trained on proper squat technique in their resistance training program prior to the study. This ensured all participants used correct technique throughout the duration of the study.
- Researchers monitored all training sessions to ensure the training protocol was followed correctly.

Definitions

Instability Resistance Training (IRT)- Instability training (IRT) is used to describe the use of an exercise variation, implement, or loading technique specifically for the purpose of reducing the stability of a trainee.

Suspended Load- Suspended load will be used to describe any weight that is hung from a barbell using straps or bands in order to decrease the stability of the load.

Unstable Load Training (ULT)- A form of instability resistance training in which the source of the instability is in the mechanism of loading.

Unstable Surface Training (UST)- Unstable surface training refers to any training performed on an unstable surface implement, including stability balls, wobble boards, foam pads, and balance discs designed to reduce an individual's points of contact with solid ground (Cressey et al., 2007).

CHAPTER II. REVIEW OF LITERATURE

Core Stability

The terms “core,” “trunk,” and “core stability” are widely used in the fields of exercise and athletics, yet may not always be clearly understood. An individual’s “core” or “trunk” refers to the lumbopelvic region of the body and includes all muscles from the diaphragm (superiorly) to the pelvic floor and hip girdle (inferiorly) (Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013; Willardson, 2007). These muscles work synergistically around and within this region to create a corset-like effect to support and stabilize the spine (Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013).

Not only does the core musculature support and stabilize the trunk region during movement, but it is also the center of the kinetic chain (Bliss & Teeple, 2005). A more stable core provides a more firm foundation, allowing the upper and lower limbs to develop greater forces and increasing the efficiency of force transfer between the upper and lower limbs (Anderson & Behm, 2005; Behm & Anderson, 2006; Behm, Drinkwater et al., 2010; Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013; Willardson, 2007). The ability of the core musculature to stabilize the entire trunk region is key to maintaining spinal alignment and optimal trunk position in addition to supporting and transferring loads and forces through all planes of movement and changes in the body’s center of gravity (Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013).

Bliss and Teeple (2005) claim “all the core muscles act in concert with one another through varied and complex movements, especially when the person is participating in sport” (p.179). Because core stability is necessary for all human movement, the dynamic movements, forces, and load transfers often experienced in athletics increases the demand for core stability, so training techniques to engage the core musculature and improve core stability must be included in strength and conditioning programs (Behm, et al., 2010; Willardson, 2007).

A multitude of research has been conducted in order to examine the various core stability training methods and their influence on muscle activity and functional performance. One branch of research has investigated stand-alone and supplemental core strength and stability programs (Bliss & Teeple, 2005; Oliver & Brezzo, 2009; Saeterbakken, Van Den Tillaar, & Seiler, 2011). Many of these programs are derived from those traditionally used in rehabilitation and injury prevention (Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013) A major limitation of these separate programs is the time cost of performing them in addition to any other training, or the exclusion of other training to incorporate an additional core stability training program. They also tend to be less sport specific than more functional exercises.

Another research avenue has focused on core muscle activation during various resistance exercises (Anderson & Behm, 2004; Anderson & Behm, 2005; Campbell et al., 2014; Goodman, Pearce, Nicholes, Gatt, & Fairweather, 2008; Kohler et al., 2010; Lawrence & Carlson, 2015; McGill, Cannon, & Andersen, 2013; Wahl & Behm, 2008). The emphasis of core muscle involvement while training using compound movements to strengthen other important muscle groups has been shown to be effective, and it also may be more time efficient for athletes.

Instability Resistance Training

Resistance training is a common practice for increasing muscular size and strength. The forces produced by the muscles to resist and move sources of external resistance cause them to adapt. Two of the most common implements used in resistance training are machines and free weights. While it is generally accepted that the reduction in stability while resistance training using free weights engages the trunk musculature greater than when using exercise machines in order to maintain balance and coordination (Behm et al., 2010; Garhammer, 1981), there are a variety of methods by which the stability of free weight exercises can be altered to further augment core muscle activation. Coaches and athletes often implement various types of IRT in order to further engage core muscles, which promotes core stability. Many of these training methods have been examined throughout the literature.

In order to reduce the stability of the trainee, most IRT exercises involve implements that create an unstable surface on which an exercise is performed. Unstable surface training (UST) often utilizes implements such as wobble boards, foam pads, inflatable disks, and stability balls which decrease stability by altering the athletes base of support (Anderson & Behm, 2004; Anderson & Behm, 2005; Behm et al., 2002; Campbell et al., 2014; Cressey et al., 2007; Goodman et al., 2008; Kibele & Behm, 2009; Kohler et al., 2010; Koshida et al., 2008; McBride et al., 2006; Oliver & Brezzo, 2009; Sparkes & Behm, 2010; Wahl & Behm, 2008; Yaggie & Campbell, 2006). Resistance, stationary, or dynamic callisthenic exercises can be performed on these implements in a bipedal (on both legs), unipedal (on one leg), seated, or lying position. Sling/suspension training is another form of instability training that allows for a variety of exercise to be performed using labile hand and foot positions (McGill et al., 2014; Saeterbakken et al., 2011). The similarity among all of these training methods is that they challenge the individual to maintain a stable body position on an unstable surface.

Rather than altering the base of support like the UST methods above, instability can also be induced by altering the method of loading of an exercise. Free weights and machines are the most common types of resistance training equipment, with the latter providing the greatest stability during movement (Anderson & Behm, 2005; Cotterman et al., 2005; Schwanbeck et al., 2009; Sparkes & Behm, 2010). Performing exercises using dumbbells rather than barbells is another method researchers have used to induce even greater instability in resistance training (Campbell et al., 2014; Kohler et al., 2010). Weight plates can also be suspended from barbells using elastic bands or non-elastic straps which allows the weights to sway as the bar is moved during the exercise (Lawrence & Carlson, 2015). All of these methods used to increase the level of instability in resistance training exercises can be applied in a variety of ways based on sport specificity, and their effectiveness and application have been studied extensively.

Muscle Activation in Instability Resistance Training

Muscle activation of the core and limb musculature is commonly analyzed when studying resistance training, instability training, balance training, and core stability training methods. A variety of studies reveal some contradictory findings involving the relationship between muscle activation and exercise instability (Anderson & Behm, 2004; Anderson & Behm, 2005; Behm et al., 2002; Campbell et al., 2014; Goodman et al., 2008; Kohler et al., 2010; Lawrence & Carlson, 2015; McBride et al., 2006; McGill et al., 2013; Schwanbeck et al., 2009; Wahl & Behm, 2008) Multiple research teams have found a positive correlation between increased exercise instability and increased muscle activation in core and joint stabilizing muscles (Anderson & Behm, 2004; Anderson & Behm, 2005; Campbell et al., 2014; Lawrence & Carlson, 2015; Schwanbeck et al., 2009). When comparing the Smith Machine squat, free squat, and free squat on balance disks, activation of the soleus, abdominal stabilizers, upper lumbar erector spinae and lumbo-sacral erector spinae was highest in the balance disk squat and lowest in the Smith machine squat (Anderson & Behm, 2005). Other research found the free weight squat elicited an average of 43% greater muscle activation across seven muscles in comparison to the Smith Machine squat (Schwanbeck et al., 2009). Another study examined coupled (barbell bench press) and uncoupled (dumbbell bench press) loads on an unstable (Swiss ball) surface (Campbell et al., 2014).

Although statistically insignificant, the results showed 15% greater muscle activation in the pectoralis major and rectus abdominus and relatively equal activation in the anterior deltoid and triceps brachii using an uncoupled load on an unstable surface compared to the coupled load, indicating a greater demand of activity for stabilization of the uncoupled load (Campbell et al., 2014). Comparison of the squat exercise with an unstable load to a stable load also revealed greater muscle activation in the rectus abdominus (85.6%), external oblique (13.1%), and soleus (72.2%) while maintaining equal activation in the vastus lateralis, vastus medius, biceps femoris, and erector spinae (Lawrence & Carlson, 2015). Anderson, and Behm (2004) compared a bench and exercise ball chest press exercise and found that equal muscle activation was achieved while producing less force on the exercise ball (Anderson & Behm, 2004). Despite the variations in the exercise type and source of instability in these studies, these data support the notion that the performance of exercises possessing a degree of instability stimulates greater muscle activation in order to maintain limb, joint, and load stability throughout the movement. This trend of increased activation is most consistent when looking at the trunk musculature.

However, there is some evidence from other research that contradicts the positive relationship between exercise instability and muscle activation. Research has found no difference in muscle activation (Goodman et al., 2008), and even decreased activation with an increase in instability (Behm et al., 2002; Kohler et al., 2010; McBride et al., 2006; Wahl & Behm, 2008). Goodman, Pearce, Nicholes, Gatt, and Fairweather (2008) compared muscle activation during a 1RM bench press on a bench and on a Swiss ball and found no difference in muscle activation across six different muscles (Goodman et al. 2008). Other research suggests that muscle activation in the agonist leg muscles is reduced during the leg extension and isometric squat as a result of decreased stability while antagonistic muscle activity is increased (Behm et al., 2002;

McBride et al., 2006). Another research team found a trend of reduced activity with increased instability across eight muscles when performing the shoulder press using different combinations of dumbbells, barbells, weight bench, and Swiss ball; however, different loads were used in each condition to accommodate the reduced stability, so decreases in load intensity could have reduced muscle activation (Kohler et al., 2010). One research team even investigated the influence different unstable surfaces had on muscle activity in highly trained male subjects. They found that increases in muscle activity only resulted from the devices with the highest levels of instability (Swiss ball and wobble board) and not in the more moderate devices (BOSU and Dyna Disk) when compared to solid ground (Wahl & Behm, 2008). Unfortunately, these studies used a variety of different load intensities, levels of instability, exercises, and muscle groups to evaluate muscle activation, making it difficult to pinpoint any firm conclusions. The unclear and sometimes contradictory data in the literature regarding muscle activation during IRT indicates that there may be limits to the extent of increased muscle activation with instability based on the role of the muscle in the movement, loading intensity, degree of instability, and training experience of the subjects.

Force Production in Instability Resistance Training

Another common measurement in exercise analysis is force production. Force production is a key component to muscular strength and power in athletes. One glaring disadvantage to IRT is that a wide body of research has shown the ability to produce maximal force is negatively affected by the degree of instability in an exercise (Anderson & Behm, 2004; Behm et al., 2002; Cotterman et al., 2005; Cressey et al., 2007; Kohler et al., 2010; Koshida et al., 2008; McBride et al., 2006). In a study comparing maximal strength in free-weight squats to Smith Machine squats, maximal strength was significantly greater using the Smith Machine than a free barbell

(Cotterman et al., 2005). Likewise, force output was reduced by almost 60% during an isometric chest press on an exercise ball compared to a bench (Anderson & Behm, 2004). An examination of strength using combinations of stable and unstable loads on both stable and unstable surfaces found that shoulder press 10RM (repetition maximum) was greatest in the most stable condition, barbell on a stable bench, and least in the least stable condition, dumbbells on a Swiss ball (Kohler et al., 2010). Reduced force outputs compared to more stable conditions have also been found in a 50% 1RM bench press on a Swiss ball versus a bench (Koshida et al., 2008), leg extension and plantar flexion while sitting on a Swiss ball versus a bench (Behm et al., 2002), and isometric squat while standing on inflatable balls versus a solid surface (McBride et al., 2006). Nearly all these researchers concluded that greater stability in an exercise allows for greater force production because less muscle activation is used to stabilize the trunk, limbs, and load (Anderson & Behm, 2004; Behm et al., 2002; Cotterman et al., 2005; Kohler et al., 2010; Koshida et al., 2008; McBride et al., 2006). Researchers investigated this common conclusion by examining the effects of training using an unstable surface (inflatable disks) on sprint speed and power production in the bounce drop jump and countermovement vertical jump in collegiate athletes. They found a significantly smaller increase in force production in the unstable surface group after ten weeks of training (Cressey et al., 2007). The researchers concluded that the reduced training load required when using an unstable surface does not induce the force production required to increase strength in trained individuals capable of greater power production (Cressey et al., 2007).

There is some work that contradicts this idea, however. When comparing the barbell 1RM chest press on a bench and on a stability ball, no significant differences were found between the stable and unstable condition (Goodman et al., 2008). A study by Sparkes and Behm

(2010) found no differences in strength gains between subjects using machine based workouts and those using a combination of dumbbell and Swiss ball equivalent exercises after 8-weeks of training (Sparkes & Behm, 2010). These data suggest that it may be possible for strength gains to be matched despite the slightly lighter loads required by the unstable condition (Sparkes & Behm, 2010). The same conclusion can be drawn from the findings of Kibele and Behm (2006) who administered stable and unstable training programs over a period of seven weeks; no differences were found in strength, balance, and functional performance (Kibele & Behm, 2006). The findings of these studies indicate that it may be possible to induce strength gains over the course of a training period by manipulating the level of instability to an intensity that allows for sufficient loading and force production for strength improvement.

Unstable Load Training

The majority of IRT research has been done on resistance training techniques that utilize an unstable surface. While UST techniques are commonly investigated, there is very little research that investigates the use of ULT techniques beyond the use of free weight barbells and dumbbells in comparison to machines. However, a recent study analyzed the force production and muscle activation in the squat exercise with the weight plates suspended from the bar using elastic bands (Lawrence & Carlson, 2015). These data were compared to that collected during the traditional squat exercise with the weight plates loaded directly on the bar, and they found equal muscle activation in the rectus femoris, vastus medius, vastus lateralis, biceps femoris, and erector spinae; greater activation in the rectus abdominus, external oblique, and soleus; and only a 3.9% decrease in vertical ground reaction force production with the unstable load (Lawrence & Carlson, 2015). Training like this on a stable surface with an unstable load may be of greater interest to athletes. In most athletic competitions, it is most commonly unstable forces and loads that must be resisted and overcome, not an unstable surface, in order for the athlete to remain upright and in a sound position to perform (Kohler et al., 2010; Willardson, 2007). Training in this way may apply more directly to the demands athletes most often face. The possibility of a minimal reduction in force combined with the increased core stabilizer activation presented by Lawrence and Carlson (2015) shows promise toward achieving maximal benefits in both balance and strength simultaneously. This method needs to be investigated over the duration of a training period to investigate its impact on performance measures in athletic populations.

Performance Tests

1 Repetition Maximum Squat (1RM Squat)

The squat exercise is a staple in most resistance training programs, and it has been used in countless exercise studies to investigate lower-body muscle function (Anderson & Behm Trunk, 2005; Cotterman et al., 2005; Lawrence & Carlson, 2015; McBride et al., 2006; Schwanbeck et al., 2009). 1RM's are commonly used to assess an individual's strength, or maximum single-effort force output.

Star Excursion Balance Test (SEBT)

The SEBT and its variations serve as practical dynamic balance field-tests (Bressel, Yonker, Kras, and Heath, 2007; Demura & Yamada, 2010; Gribble & Hertel, 2003; Gribble, Kelly, Refshauge, & Hiller, 2013; Hyong & Kim, 2014). The test requires the participant to stand on one leg while reaching out along eight lines positioned 45 degrees apart with the other foot to a maximum distance while maintaining the unipedal base of support. The average of three trials or maximum distance reached in each direction is measured and divided by the subject's leg length in order to normalize the scores (Gribble & Hertel, 2003). The normalized measurements for each direction can then be analyzed separately or added together to create one score (Bressel et al., 2007). Although there are other methods for assessing static and dynamic balance using force plates and computer software, administering the SEBT is much more practical in the field. Researchers have found the complete SEBT and its 3-trial, 4-direction variation (anterior, medial, posterior, and lateral) to be a valid and reliable test of dynamic balance (Demura & Yamada, 2010; Gribble, Kelly, Refshauge, & Hiller, 2013; Hyong & Kim, 2014).

T-Test

The T-Test is a commonly used agility test, and it has been widely used throughout the literature as an assessment tool (Baechle and Earle, 2008; Cressey et al., 2007; Sekulic, Spasic, Mirkov, Cavar, & Sattler, 2013). This timed test requires the participant to sprint, shuffle, and backpedal over short distances while trying to maximize speed and change of direction. The T-Test has been found to be a reliable and valid measure of agility (Pauole, Madole, Garhammer, Lacourse, & Rozenek, 2000; Stewart, Turner, and Miller, 2014).

Vertical Jump Height

Maximum vertical jump height is a common lower-body power measure (Baechle & Earle, 2008; Cressey et al., 2007; Sparkes & Behm, 2010; Yaggie & Campbell, 2006). Power is a key element in most athletic activities as force must often be produced in a very short period of time. Although power generation may occur in nearly all the muscles and in all planes of movement, the coutermovement vertical jump is a very common athletic activity and has been shown to be a valid and reliable assessment tool while remaining relatively easy to administer (Markovic, Dizdar, Jukic, & Cardinale, 2004).

Conclusion

There is a wide variety of training techniques designed to induce instability in common resistance exercises. Varying levels of surface and load stability have been applied to trunk/core, upper-body, and lower-body exercises. The research investigating these methods has produced inconsistent results regarding their impact on muscle activation, force production, strength, and functional performance. The lack of agreement within the body of research in defining these relationships indicates that factors such as subject training experience, level of instability, source of instability (surface vs. load), and type of exercise (core vs. lower- vs. upper-body) could all independently influence training outcomes. As a result of the lack of the inconclusive research, it is unclear whether IRT can produce a more effective training stimulus than traditional free-weight training methods. It remains to be determined whether these factors, primarily the load intensity and level of instability, can be tailored to produce desired training outcomes in athletes.

CHAPTER III. METHODS

Introduction

The purpose of this study was to analyze the effect of performing the squat exercise with suspended weight on maximal strength, dynamic balance, agility, and power in collegiate athletes. The quantitative experimental design was created to answer three questions:

- Does performing the squat exercise with a suspended load elicit the same strength improvement as conventional loading in the squat exercise after a six-week resistance training program?
- Does performing the squat exercise with a suspended load elicit greater balance improvement than the conventional squat after a six-week training program?
- Does performing the squat exercise with a suspended load influence agility and power differently than the conventional squat after a six-week training program?

Answering these questions could provide valuable information regarding the methods of loading in resistance training exercises designed to enhance the performance of competitive athletes.

Participants

This study included 38 male collegiate baseball players from Mayville State University (MSU). Permission was received from the MSU Baseball Coaching Staff to test the athletes on their roster and implement our experimental intervention into their off-season strength and conditioning program. All subjects signed consent forms warning of the possibility of injury during resistance training, and they were cleared by the MSU Athletic Training Staff to complete maximal strength testing in the squat exercise in addition to agility, vertical jump height, and balance testing. Roster players were excluded from the study if they were under 18 years old, could not complete maximal strength, balance, vertical jump, or agility testing, or were not cleared by the MSU Athletic Training Staff to participate in maximal testing or the entire resistance training program. Subjects who attended less than 80% of the training sessions were also excluded from the final data analysis. Participants were allowed to withdraw from the study without affecting their status on the team. Six subjects were omitted from the final analysis as a result of the exclusion criteria. Three sustained injuries (2 ankle, 1 hamstring) that prevented them from completing the required number of training sessions. These injuries occurred during the speed/agility portion of training and were not related to the experimental squat exercise. One subject voluntarily withdrew from the study when he quit the team, and two were unable to achieve sufficient squat depth during 1RM squat testing. The 32 subjects' average age (years), year of participation, stature (inches), and body weight (lbs.) were 20.31, 2.84, 71.47, and 189.63. All subjects had a minimum of eight weeks of resistance training experience with the coaching staff at MSU, and they recently completed an eight-week training period focusing on muscular hypertrophy.

Research Design

After Institutional Review Board approval from North Dakota State University and MSU, this research was conducted at the MSU training facility. MSU resistance training equipment was used for maximal strength testing and the resistance training program.

This study utilized a repeated measures randomized experimental design with the independent variable being the mechanism of loading on the barbell in the squat exercise. The use of a conventionally loaded barbell was compared to a load in which all of the weight plates were suspended from the barbell using Spud, Inc. Stump Straps (Stump Straps; Spud, Inc., Columbia, South Carolina, USA). The dependent variables measured were one repetition maximum (1RM) in the squat exercise, Star Excursion Balance Test (SEBT) score, T-test time, and max vertical jump height. Subjects were randomly assigned to experimental (suspended loading) or control (conventional loading) groups and participated in a six-week resistance training program. The experimental loading technique was only applied to the squat exercise throughout the training period. Changes in pre- and post-training measurements of 1RM squat, dynamic balance, agility, and power were compared between groups upon completion of the data collection.

Procedures

During the week prior to beginning the six-week resistance training program, the height, weight, age, and year of participation in a college baseball program of all subjects was measured and recorded. Pre-testing was divided into two consecutive two-hour testing days beginning four days prior to starting the training program. The two-hour period was divided into 30-minute sessions during which 10-12 athletes completed the assigned tests.

On the first day of testing, subjects completed a five-minute dynamic warm-up (Table 1), followed by a maximum vertical jump test using a Vertec (Sports Imports, Hilliard, OH, USA), the T-test, and the SEBT. Testing in maximum vertical jump height and the T-test was completed to obtain a measure of muscular power and agility respectively. When testing maximum vertical jump height, a countermovement vertical jump with arm swing was used, and the best of three trials was recorded (Baechle & Earle, 2008). The T-test was also completed consistent with the protocol described by Baechle and Earle (2008), and the best time of two trials was recorded.

Subjects’ balance was then assessed using the 3-trial, 4-direction SEBT, as described by Demura and Yamada (2010). To complete testing, two intersecting perpendicular lines were marked on the ground with athletic tape. After three minutes of practice, the subject stood in the center of the intersection on his dominant leg and completed three consecutive trials in the anterior, medial, posterior, and lateral directions. Each trial distance was marked with the researcher's finger and measured from the center of the intersection. The maximum distance reached from the center of the intersection was measured, recorded, and normalized as a percentage of leg length (reach distance/leg length x 100) (Gribble & Hertel, 2003). The sum of the four normalized scores was used to create a single test score (Bressel et al., 2007).

On the second testing day, subjects completed the same five-minute dynamic warm-up followed by 1RM testing in the squat exercise using an established 1RM testing protocol (Baechle & Earle, 2008). Members of the research team monitored the subjects to ensure that they used proper squat technique and that sufficient depth (upper-leg parallel to the floor) was achieved during each repetition.

After pre-testing was completed, subjects were assigned identification numbers, sorted based on their years of participation in a college athletic program to indicate training age, and randomly assigned to either the experimental (19 subjects) or control groups (19 subjects). For the duration of the resistance training program, the experimental group performed the squat exercise using Stump Straps (Spud, Inc., Columbia, South Carolina, USA) to suspend all of the weight plates from the barbell. The control group performed the squat exercise with conventional loading of weight plates on the barbell throughout the training program. The suspended load intervention was only applied in the squat exercise. All additional exercises in the program were performed identically by both groups.

The resistance training program used in this study was the current MSU Baseball off-season training program. It was focused on maximal strength improvement, and the athletes were not participating in any other practice or training sessions during the study. Each resistance training session consisted of approximately 15-minutes of the same dynamic warm-up that was completed prior to the pre-test along with mobility exercises (Table 2), 15-minutes of assorted agility training drills (Table 3), 45-60 minutes of resistance training (Table 4), and 15-minutes of flexibility training.

The resistance training portion was a two-day, upper- and lower-body split design with four training days/week (lower-body, upper-body, rest, lower-body, upper-body, rest, rest). Examples of each portion of a typical training day are described in Tables 1-4. The training load used by each subject was the maximum amount that allowed for completion of all of the prescribed number of repetitions. Subjects gradually increased the load in each exercise throughout the training period as their ability to achieve the prescribed repetitions improved. A member of the research team observed each training session.

Subjects were again tested for 1RM squat, dynamic balance, vertical jump height, and agility three and four days after completion of the six-week program using the same procedures as the pre-test. The pre- and post-test values of both groups were compared to determine if there were any differences in training outcomes between the experimental and control groups.

Statistical Analysis

Data collected from the pre- and post-tests for 1RM squat, dynamic balance, vertical jump height, and agility were used to analyze any difference in improvement between the experimental and control groups over the training period. The mean change in 1RM squat, dynamic balance, vertical jump height, and agility in both groups was calculated and compared using a repeated-measures analyses of variance (ANOVA). Level of statistical significance was set to $p<0.05$. Post-hoc analyses were conducted if any significant interactions were found. The post-hoc tests included independent and paired samples t-tests and utilized a Bonferroni corrected p-value of $p \leq 0.0125$. SPSS software was used to perform all statistical analyses.

Conclusion

This experimental study sought to analyze the impact of performing the squat exercise with a suspended load over the course of a six-week total body resistance training period. Specifically, we aimed to discover how suspended loading in the squat exercise affected maximal strength, dynamic balance, agility, and power in collegiate baseball players in comparison to conventional loading methods. Our results could help reveal how different loading techniques in resistance training impact performance outcomes in competitive athletes.

CHAPTER IV. MANUSCRIPT FOR PUBLICATION

Introduction

Success in athletics requires a broad range of physical skills. Athletes use a variety of training techniques to enhance skills such as speed, strength, and power. Postural balance is another skill that influences athletic performance. Successful athletic performance greatly depends on the body's ability to maintain upright posture during forward, backward, and lateral movements (Yaggie & Campbell, 2006). This can be achieved through the strengthening and improved coordination of the core stabilizing muscles. The core is comprised of the abdominal, oblique, gluteal, and paraspinal muscle groups, in addition to the diaphragm, pelvic floor, and hip girdle; together these muscles surround the trunk region and support the spine (Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013; Willardson, 2007). Research has shown that a strong core creates a firm foundation for limb movement (Anderson & Behm, 2005; Behm & Anderson, 2006; Behm, Drinkwater, Willardson, & Cowley, 2010; Bliss & Teeple, 2005; Huxel Bliven & Anderson, 2013; Willardson, 2007).

Studies have linked greater muscle activation in the core to unstable exercises that require greater body stabilization (Campbell, Kutz, Morgan, Fullenkamp, & Ballenger, 2014; Schwanbeck, Chilibeck, & Binsted, 2009). Training under unstable conditions challenges the neuromuscular system in a way that replicates the demands faced while performing many sports tasks (Behm et al., 2010; Kibele & Behm, 2009; Willardson, 2007). In order to improve their ability to react to the dynamic movements and variable forces experienced in most athletic environments, many athletes are beginning to implement balance training and instability resistance training (IRT) techniques in addition to resistance training traditionally geared toward speed, strength, and power development (Yaggie & Campbell, 2006).

Despite the core strength and stability benefits of IRT, however, it may not be as effective at muscular strength and power development in the limb musculature. Improving these areas requires an athlete to generate near maximal muscular force in their training. Research shows that exercise under unstable conditions tends to result in reduced muscular force production (Anderson & Behm, 2004; Behm, Anderson, & Curnew, 2002; Cotterman, Darby, & Skelly, 2005; Cressey, West, Tiberio, Kraemer, & Maresh, 2007; Kohler, Flanagan, & Whiting, 2010; Koshida, Urabe, Miyashita, Iwai, and Kagimori, 2008; McBride, Cormie, & Deane, 2006). Generally, IRT requires a lighter training load because more muscle activation is used for stability rather than muscular force production (Anderson & Behm, 2004; Behm et al., 2002; Cotterman et al., 2005; Kohler et al., 2010; Koshida et al., 2008; McBride et al., 2006). The reduced load is often insufficient to cause strength improvement because near maximal muscular force is not being achieved (Cressey et al., 2007). In contrast to these findings, other studies have found no difference in strength gains between stable and unstable training programs (Kibele & Behm 2009; Sparkes & Behm, 2010). This disagreement suggests that factors such as the degree and source of instability in an exercise may determine its ability to improve muscular strength.

There is little research analyzing the effect of IRT techniques and programs on performance measures such as power, agility, and balance. There is also limited research investigating IRT with unstable loads rather than an unstable surface, especially using suspended training loads rather than conventional loading on a barbell. Unstable load training (ULT) may relate better to athletics because the source of instability is in the load rather than the contact point between the feet and the ground. One study, however, has found ULT with suspended weight to elicit greater muscle activation in the core musculature while creating only minor decreases in force production (Lawrence & Carlson, 2015). The combination of balance training with resistance training is ideal when the level of instability is great enough to elicit improvements in balance via core stabilization, yet low enough to allow for maximal force production (Behm & Anderson, 2006). Therefore, the purpose of the present study was to analyze the effects of performing the squat exercise with suspended weight within a six-week resistance training program on dynamic balance, maximal strength, agility, and power in collegiate male athletes. The present study sought to answer three research questions: 1) Does performing the squat exercise with a suspended load elicit the same strength improvement as conventional loading in the squat exercise after a six-week resistance training program? 2) Does performing the squat exercise with a suspended load elicit greater balance improvement than the conventional squat after a six-week training program? 3) Does performing the squat exercise with a suspended load influence agility and power differently than the conventional squat after a six-week training program? If balance, agility, and/or power improvements are greater in the experimental group without a reduction in maximal strength increases when compared to the standard squat control group, it may be possible that training using suspended loads is a more effective way for athletes to train. With athletes continually striving to maximize their performance, it is important to assess the efficacy and specificity of the available training methods.

Methods

Experimental Approach to the Problem

This study used a repeated measures randomized experimental design to assess differences in performance adaptations as a result of training with conventional or suspended loading in the squat exercise. NAIA baseball players with resistance training experience participated in identical six-week off-season resistance training programs. They were randomly assigned to either control (conventional) or experimental (suspended) loading conditions during the squat exercise. All other exercises in the program were performed with conventional loading. 1RM squat strength, dynamic balance, vertical jump, and agility performance were tested pre- and post-training and compared to examine any differences between groups.

Subjects

Thirty-eight male collegiate baseball players from Mayville State University (MSU) were randomly distributed into two training groups. Permission was received from the MSU Baseball Coaching Staff to test the athletes on their roster and implement our experimental intervention into their off-season strength and conditioning program. Roster players were excluded from the study if they were under 18 years old, could not complete maximal strength, balance, vertical jump, or agility testing, or were not cleared by the MSU Athletic Training Staff to participate in maximal testing or the entire resistance training program. Subjects who attended less than 80% of the training sessions were also excluded from the final data analysis. Participants were allowed to withdraw from the study without affecting their status on the team. Six subjects were omitted from the final analysis as a result of the exclusion criteria. Three sustained injuries (2 ankle, 1 hamstring), which prevented them from completing the required number of training sessions. These injuries occurred during the agility portion of the training program and were unrelated to the squat exercise and experimental design. One subject voluntarily withdrew from the study when he quit the team, and two were unable to achieve sufficient squat depth during 1RM squat testing. The 32 subjects' average age (years), year of participation, stature (inches), and body weight (lbs.) were 20.31, 2.84, 71.47, and 189.63. All subjects had a minimum of eight weeks of resistance training experience with the coaching staff at MSU, and they had recently completed an eight-week training period focusing on muscular hypertrophy.

Subjects were informed of the experimental risks and signed informed consent documents prior to participation. The present investigation was approved by the North Dakota State University Institutional Review Board for research on human subjects.

Procedures

Performance Testing

During the week prior to beginning the six-week resistance training program, the height, weight, age, and years of participation in a college baseball program of all subjects was measured and recorded. Pre-testing was divided into two consecutive two-hour testing days beginning four days prior to starting the training program. The two-hour period was divided into 30-minute sessions during which 10-12 athletes completed the assigned tests.

On the first day of testing, subjects completed a five-minute dynamic warm-up (Table 1), followed by a maximum vertical jump test using a Vertec (Sports Imports, Hilliard, OH, USA), the T-test, and the Star Excursion Balance Test (SEBT). Testing in maximum vertical jump height and the T-test was completed to obtain a measure of muscular power and agility respectively. When testing maximum vertical jump height, a countermovement vertical jump with arm swing was used, and the best of three trials was recorded (Baechle & Earle, 2008). The T-test was also completed consistent with the protocol described by Baechle and Earle (2008), and the best time of two trials was recorded.

Subjects' balance was then assessed using the 3-trial, 4-direction SEBT, as described by Demura and Yamada (2010). To complete testing, two intersecting perpendicular lines were marked on the ground with athletic tape. After three minutes of practice, the subject stood in the center of the intersection on his dominant leg and completed three consecutive trials in the anterior, medial, posterior, and lateral directions. Each trial distance was marked with the researcher's finger and measured from the center of the intersection. The maximum distance reached from the center of the intersection was measured, recorded, and normalized as a percentage of leg length (reach distance/leg length x 100) (Gribble & Hertel, 2003). The sum of the four normalized scores was used to create a single test score (Bressel et al., 2007).

On the second testing day, subjects completed the same five-minute dynamic warm-up followed by 1RM testing in the squat exercise using an established 1RM testing protocol (Baechle & Earle, 2008). Members of the research team monitored the subjects to ensure that they used proper squat technique and that sufficient depth (upper-leg parallel to the floor) was achieved during each repetition.

Table 1
Dynamic Warm-Up

Exercise	Distance
High Knees	Half Court
Butt Kicks	Half Court
Forward Lunge	Half Court
Backward Lunge	Half Court
Side Lunge	Half Court Right, Half Court Left
Frankenstein's	Half Court
RDLs	Half Court
Heel/Toe Walks	Half Court Heels, Half Court Toes
Side Shuffle	Half Court Right, Half Court Left
Kareoka	Full Court Right, Full Court Left
Skip for Height	Full Court
Skip for Distance	Full Court

Training Program

After pre-testing was completed, subjects were assigned identification numbers, sorted based on their years of participation in a college athletic program as an indicator of training age, and randomly assigned to either the experimental (19 subjects) or control groups (19 subjects). For the duration of the resistance training program, the suspended group performed the squat exercise using Stump Straps (Spud, Inc., Columbia, South Carolina, USA) to suspend all of the weight plates from the barbell. The conventional group performed the squat exercise with conventional loading of weight plates on the barbell throughout the training program. The suspended load intervention was only applied in the squat exercise. All additional exercises within the program were performed identically by both groups.

The resistance training program used in this study was the current MSU Baseball off-season training program. It was focused on maximal strength improvement, and the athletes were not participating in any other practice or training sessions during the study. Each resistance training session consisted of approximately 15-minutes of the same dynamic warm-up that was completed prior to the pre-test along with mobility exercises (Table 2), 15-minutes of assorted agility training drills (Table 3), 45-60 minutes of resistance training (Table 4), and 15-minutes of flexibility training.

Table 2
Mobility Exercises

Exercise	Reps
Arm Circles	20 Forward, 20 Backward
Bodyweight Squats	10
Goodmornings	10
Pushups	10
Cat/Cow	10 each
Knee Hurdles	5 forward, 5 backward each leg
T-Spine Sprinklers	10 each side
Knee Wipers	10 each side
Hip Bridges	15
Scorpions	10 each side

The resistance training portion was a two-day, upper- and lower-body split design with four training days/week (lower-body, upper-body, rest, lower-body, upper-body, rest, rest). Examples of each portion of a typical training day are described in Tables 1-4. The training load used by each subject was estimated by an assistant strength and conditioning coach. This weight was near the maximum amount that would allow for the completion of all of the prescribed repetitions. The load used in each exercise throughout the training period gradually increased as the subjects' ability to achieve the prescribed repetitions improved. A member of the research team observed each training session.

Table 3
Sample Agility Training Day

Exercise	Sets	Reps/Duration
Double Leg Forward Line Hops	2	10sec.
Double Leg Lateral Line Hops	2	10sec.
Single Leg Forward Line Hops	2	6sec.
Single Leg Lateral Line Hops	2	6 sec.
Partner Pro-Agility	6	1
60yd. Shuttle Run	3	1

Table 4
Sample Resistance Training Days

Exercise	Sets	Reps
Upper-Body Day		
Dumbbell Bench Press	4	6
Pullups	3	Max
Pushup Combo	3	5 clap + 15
Barbell Row	3	8
Dips	3	8
Single Arm Dumbbell Row	3	10
Lower-body Day		
Squat	4	4
Sumo Deadlift	4	6
Single Leg Squat	3	6
RDL	3	6
Side Lunge	2	15
3-way Shoulder Raise	3	10

On the third and fourth days following the completion of the six-week program, all subjects were again tested for 1RM squat, dynamic balance, vertical jump height, and agility. The same procedures as the pre-test were used for each of these tests. The pre- and post-test values of both groups were compared to determine if there were any differences in training outcomes between the experimental and control groups.

Statistical Analyses

Data collected from the pre- and post-tests for 1RM squat, dynamic balance, vertical jump height, and agility were used to analyze any difference in improvement between the experimental and control groups over the training period. The mean change in 1RM squat, dynamic balance, vertical jump height, and agility in both groups was calculated and compared using a repeated-measures analyses of variance (ANOVA). Level of statistical significance was set to $p<0.05$. Post-hoc analyses were conducted if any significant interactions were found. The post-hoc tests included independent and paired samples t-tests. Both of these utilized a Bonferroni corrected p-value of $p \leq 0.0125$. SPSS software was used to perform all statistical analyses.

Results

1RM Squat Strength. There was no significant interaction between the main effect of time and group (F=0.888, p=0.353, ES: 0.029). Both groups experienced a significant (F=26.425, p=0.0001, ES: 0.468) main effect of time in 1RM squat performance.

SEBT. There was no significant interaction between the main effect of time and group (F=0.623, p=0.436, ES: 0.020). The main effect of time was not significant (F=1.974, p=0.170, ES: 0.062) for either group in SEBT performance.

T-test Agility. There was not a significant interaction between the main effect of time and group (F=0.024, p=0.878, ES: 0.001), but both groups experienced a significant (F=4.755, p=0.037, ES: 0.137) main effect of time in T-test performance.

Vertical Jump. There was a significant ($F=4.715$, $p=0.038$, ES: 0.136) interaction between time and group in vertical jump performance. The independent samples t-test revealed no significant difference between groups at pretesting ($t=-1.528$, $p=0.137$) according to the Bonferroni corrected p-value of $p \leq 0.0125$, but the difference between groups at post-testing approached significance ($t=-2.342$, $p=0.026$). The paired samples t-test also found a difference that approached significance ($t=-2.471$, $p=0.026$) between the suspended groups' pre- and post-test vertical jump performance according to the Bonferroni corrected value of $p \leq 0.0125$. There was no significant difference between pre- post-test performance in the conventional group ($t=0.650$, $p=0.525$). The main effect of time was not significant ($F=1.506$, $p=0.229$, ES: 0.048) for either group in vertical jump performance.

Discussion

One of the most notable findings of the present study was the significant improvement of both the suspended (6.9%) and conventional (4.5%) groups in 1RM squat performance and the lack of a significant main effect in either group or between groups in SEBT performance. The similar improvement in squat strength by both groups indicates that the instability created by the suspended load did not reduce force output to a level that would inhibit maximal squat strength improvement. These data answer the first research question of whether performing the squat exercise with an unstable load could produce similar strength improvements to those achieved in the traditional loading condition. These findings agree with the previous research that contends that IRT techniques can elicit maximal strength increases despite the reduced stability for force production (Goodman et al., 2008; Kibele & Behm 2006; Sparkes & Behm, 2010). The disagreement in the research regarding the ability of IRT methods to improve maximal strength seems to depend on the level of instability of the individual exercise. Our results suggest that

ULT with a suspended load allows for sufficient force production while introducing an unstable component above the base of support similar to situations commonly faced in athletics. Although statistically insignificant, there was approximately 2.5% greater improvement by the suspended group over the six week training period. This could warrant further investigation, especially, given the population studied was NAIA collegiate athletes that likely have higher starting strength, agility, balance, and power compared to recreational athletes or age matched college students.

Contrary to our hypothesis, however, there was not a significant main effect in SEBT performance. This demonstrates that the instability associated with the suspended load condition was not sufficient to induce a significant improvement in dynamic balance as indicated by SEBT score over a six week training period. The lack of dynamic balance improvement could be a result of a number of factors. The six weeks of training may not have been a long enough time period for unstable load training to elicit balance improvements. Previous IRT and balance research has used anywhere from 4-10 week training periods to entire competitive seasons (Cressey et al., 2007; Kibele & Behm, 2009; Myer et al., 2006; Oliver & Brezzo, 2009; Saeterbakken et al., 2011, Sparkes & Behm, 2010; Yaggie & Campbell, 2006). To our knowledge, no other studies have examined the training effects of suspended loading over the course of a training period. It is possible that suspended loading in resistance exercise may require a longer training duration to elicit dynamic balance adaptations.

It is also possible that the SEBT may not have been sensitive enough to detect any changes in stability or balance that may have occurred compared to a force plate's ability to detect the postural sway. During the squat exercise, the feet remain stationary and there is little if any movement outside the base of support. The one-footed stance and reaching required in the

SEBT are relatively dissimilar to the squatting motion; however, the SEBT was selected for this reason in order to best represent the dynamic movements demanded by most athletic activities in order to examine the suspended load's impact on stability during sport specific movements. Any improvement in stationary stability or reduction in postural sway that may have resulted from training may not have impacted SEBT score.

Another key finding occurred in the analysis of the results of the maximum vertical jump test, which was used to test lower body power in the subjects. There was no significant main effect of time in vertical jump height, but the suspended condition resulted in a 2.27% increase whereas the conventional group showed a minimal decrease of 0.70%. A significant interaction was found between the main effect of time and groups in which the change from pre- to post-test in the suspended group approached significance (p=0.026) using our conservative post-hoc Bonferroni test to control for type I error inflation. The vertical jump requires core stability to counter high velocity flexion and extension of the torso during a maximum effort jump. Despite the squat exercise being a relatively slow movement, the high loads used in the present study in combination with unstable loading may have created an intensity level that is more similar to the vertical jump. Although technically statistically insignificant, the trends for slightly greater improvement by the conventional group in the high velocity agility and vertical jump tests may suggest that the benefits of high intensity (high load) ULT are only noticeable in high intensity movements involving greater forces and/or movement velocities. The SEBT is a challenging test of dynamic balance, but the movements are relatively slow and have no external resistance. The internal and external forces experienced during the SEBT may simply not be great enough to utilize the adaptations that may have resulted from the ULT in the present study.

In addition to strength improvement, both groups demonstrated a significant main effect of time in agility as measured by the T-test, but there were no significant differences between groups. This indicates that the training program, which included agility and speed training components, was effective in developing these characteristics. The suspended group reduced their T-test time by 1.23%, while the conventional group showed a mean reduction of 1.0%. Although statistically insignificant, the greater improvement made by the suspended group may warrant further investigation assessing the influence of suspended load training on other agility measures.

There are a few limitations to the present study. One is that ULT was only applied to one exercise (squat) within the training program. MSU Baseball's off-season training program included speed/agility training and multiple other lower- and upper-body exercises. Implementation of an unstable load is not possible in all exercises, but a greater effect may have been observed if more UL exercises were included within the experimental training program. A possible future research endeavor could compare two training programs consisting entirely of either unstable or traditionally loaded free weight exercises.

It is also possible that six weeks was not long enough to develop significant power and dynamic balance adaptations in trained college athletes irrespective of the mechanism of loading. A longer training period could also have brought out greater main effects of time in strength and agility in addition to revealing more clear differences that may have developed between the suspended and conventional groups.

As mentioned above, the SEBT may not have been the best measure of the core stability adaptations that may have resulted from training with an unstable load in the squat exercise. The SEBT was chosen because it is a field test that can be easily administered outside a laboratory setting. The challenge of reaching while maintaining balance on one leg that this test presents was also a factor in its selection. More precise measurement tools, such as a force plate, could have been used, but the SEBT, in addition to the 1RM squat, T-test, and maximal vertical jump are all more practical methods of measurement. Each of these tests also directly measures a desirable aspect of athletic performance that is commonly utilized in competition and practice settings. This makes them much more likely to be utilized by coaches to measure performance in their athletes.

Practical Applications

IRT methods are commonly performed to increase core muscle activation during resistance training exercises. However, the ability to produce force under unstable conditions seems to depend on the level of instability in an exercise. ULT with suspended weight seems to show promise as a form of IRT that increases core muscle activation while minimally decreasing force output (Lawrence & Carlson, 2015). The aim of the present study was to analyze whether these characteristics result in enhanced training adaptations when suspended loads are applied to the squat exercise throughout a training period. Our results showed that both groups performing either suspended or conventionally loaded squats as part of a resistance training program significantly increased 1RM squat performance after six weeks of training. In fact, the suspended training group saw slightly greater (but not statistically greater) improvement in squat strength (6.9%) than the conventional group (4.5%). This indicates that the suspended load squat offered sufficient stability to generate the force needed to significantly improve maximal strength. The present study also found significant agility improvements in both groups, with the suspended group's improvement being slightly greater. Although no significant main effect of time was found in vertical jump height, the greater improvement by the suspended group was noteworthy.

The present study found no statistical differences between group improvement in SEBT performance. Although the use of unstable loading revealed no significant advantages in producing agility, vertical jump, or dynamic balance improvements over the training period, the trends for greater increases in vertical jump and T-test performance by the suspended group may warrant further research on ULT for athletic performance.

CHAPTER V. SUMMARY AND CONCLUSIONS

Athletes use a variety of resistance training techniques in order to maximize desired training adaptations such as strength, power, speed, agility, and balance. Each of these characteristics plays a role in overall athletic performance. As training methods evolve to address these different training goals, it is important to examine their effectiveness.

IRT is a technique that utilizes a multitude of exercise variations and implements to increase the difficulty of a resistance training exercise by reducing its stability. A goal of IRT is to augment core stability and balance adaptations following periods of resistance exercise. Past research teams have questioned whether adequate force outputs can be achieved in order to increase maximal strength using IRT methods. The resulting inconsistencies in their conclusions seem to stem from inherent differences in the degree of instability of each IRT technique. This may mean that it is possible to improve maximal strength and dynamic balance simultaneously.

Much of the previous IRT research examines UST techniques, which induce instability at the contact point between the body and supporting surface. In ULT, however, it is the load where the unstable component is applied. This technique may appeal to athletes because it forces them to combat an unstable force while maintaining a stable base of support, similar to many athletic movement demands. Little research has been conducted analyzing the effectiveness of training with an unstable load; however, one promising study found suspended loading in the squat exercise to elicit greater core muscle activation than the traditional squat, while exhibiting only minor decreases in force output (Lawrence & Carlson, 2015). Therefore, the aim of the present study was to examine the different training effects that may result from these differences in force output and muscle activation after a six-week training period. The inclusion of either the conventional or suspended load squat in a college baseball strength training program was compared in order to examine their influence on strength, power, agility, and dynamic balance adaptations.

Most notably, the results of the present study revealed similar significant increases in 1RM squat strength by both the suspended and conventional groups. This indicates that the level of instability created by ULT with suspended loads is low enough to allow for adequate force production to improve maximal strength. Both groups also significantly increased their agility over the training period as measured by the T-test. There were no significant increases by either group, however, in dynamic balance or vertical jump height. Although there was no statistically significant main effect of time, there was a significant interaction between time and group for vertical jump, with the suspended group achieving greater improvements. The trends of increased strength, agility, and power improvements may indicate an advantage to training with suspended loads and warrant further research.

The lack of a notable change in SEBT score is somewhat puzzling. The suspended load reduced stability within the squat, which the body is forced to combat throughout the squat movement. The hypothesis that this would result in improved dynamic balance training adaptations was not supported by our findings, however. While these results suggest that the unstable condition did not induce greater balance improvements, which is entirely possible, it is equally possible that the SEBT was not the best indicator of the core stability adaptations that may have occurred in the present study. Future research assessing ULT’s influence on other measures of balance and/or core stability may yield different results.

The results of the present study did not reveal any significant advantages or disadvantages to using suspended weight resistance training within a college baseball strength training program, but the trends for greater improvement in strength, agility, and power by the suspended group may warrant further investigation. Future research utilizing longer training periods, different UL exercises, or different performance measures may reveal different training effects for ULT using unstable loads. Also, the present study only applied the suspended load condition to the squat exercise. Both groups performed additional upper- and lower-body resistance exercises, agility drills, and speed drills within the program. The inclusion of these additional exercises may have mitigated the differences in training effects between the experimental and control groups. Because not all exercises can be performed with suspended loads, however, the inclusion of both suspended load and traditionally loaded exercises within a resistance training program geared toward athletic performance is likely how this method of IRT would most commonly be used. It is important to assess ULT in this context. To further analyze the specific training effects of suspended loading, future research could also compare training programs consisting entirely of either suspended or traditionally loaded barbell exercises.

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APPENDIX A. CONSENT FORM

NDSU North Dakota State University
Department of Health, Nutrition, and Exercise Sciences
PO Box 6050
Fargo, ND 58108-6050
320-304-4804

Title of Research Study: The Effect of Suspended Weight Resistance Training on Dynamic Balance, Muscular Strength, Muscular Power, and Agility in Collegiate Athletes.

This study is being conducted by: Bryan Christensen, PhD, NDSU Associate Professor-Exercise Science, bryan.christensen.1@ndsu.edu; Sam Thielen, NDSU Graduate Student, samuel.thielen@ndsu.edu

Why am I being asked to take part in this research study? You are being asked to participate in this study because you are: 1) a healthy, adult male, collegiate athlete, 2) you are on the Mayville State University Baseball Roster, 3) you will be taking part in the MSU Baseball off-season strength and conditioning program. You are not eligible for this study if you are under 18 years old, are unable to fully participate in the strength and conditioning program or the tests included in this study, and/or fail to complete at least 80% of the training sessions.

What is the reason for doing the study? The purpose of this study is to examine the effect of performing the squat exercise with suspended weight on maximum muscular strength, dynamic balance, muscular power, and agility in college athletes.

What will I be asked to do?
Pre-Testing:
You will be assigned a time on consecutive days to complete testing in groups of 10-12. During the first testing session, you will complete a dynamic warm-up, followed by maximum vertical jump, agility (T-test), and dynamic balance (Star Excursion Balance Test) testing. The following day you will complete a dynamic warm-up followed by a one repetition maximum (1RM) squat test.

Training Program:

You will be randomly placed in one of two groups for the duration of the MSU Baseball off-season strength and conditioning program. As part of the program, the control group will perform the squat exercise with the weight conventionally loaded on the bar. The experimental group will load the weight on the bar as directed by the research team using straps to suspend the weight. All other aspects of the training program will be performed identically by both groups.

Post-Testing:

Upon completion of the training program, you will again be assigned to a testing group on two consecutive days in order to re-test. Post-testing will follow the same protocol as the initial testing sessions.

Where is the study going to take place, and how long will it take? This study will take place in the MSU Field House and Wellness Center Gym. Each pre- and post-testing session will take approximately 30 minutes (2 total hours over 4 testing sessions). The training program will take 1.5-2 hours, 4 days/week for 6 weeks.

What are the risks and discomforts? The primary risk of this study is that of muscle or joint injury associated with resistance training. There is also a risk of muscle soreness. It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known risks to the participant**.** If new findings develop during the course of this research, which may change your willingness to participate, we will tell you about these findings.

What are the benefits to me? You may experience improvements in muscular strength, dynamic balance, muscular power, and/or agility as a result of this study. However, you may not get any benefit for participating. As a student, you may gain some benefit by seeing how experimental research is performed.

What are the benefits to other people? This research can potentially increase the knowledge of the exercise science community regarding mechanisms of loading in resistance training.

Do I have to take part in the study? Your participation in this research is your choice. If you choose not to participate, you will complete the training program without intervention, and your information will not be used in this study. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled from Mayville State University, the Mayville State University Baseball Team, or North Dakota State University. Inform one of the researchers immediately if you would like to discontinue the study.

What will it cost me to participate? There is no monetary cost to participate. This study will require two additional hours (pre- and post-testing) outside of the time required for the MSU off-season strength and conditioning program.

What are the alternatives to being in this research study? Instead of being in this research study, you can choose not to participate in which case your information will not be collected, recorded, or used for analysis.

Who will see the information that I give? Your name will be documented in a password protected computer that only Sam Thielen and the MSU Baseball coaching staff will have access to. When you are selected for a group, you will be given an identification number by which you will be referred to for the duration of the study. We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. When we write about the study, we will write about the combined information that we have gathered. We may publish the results of the study; however, we will keep your name and other identifying information private. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock.

If you withdraw before the research is over, your information will be removed, and we will not collect additional information about you.

Can my taking part in the study end early? You will be removed from the study early if you fail to participate in 20% of the total testing sessions or upon your request.

What happens if I am injured because of this research?
If you receive an injury in the course of taking part in the research, you should contact Dr. Bryan Christensen at the following phone number (701) 231-5590 or Sam Thielen at the following phone number (320) 304-4804. Treatment for the injury will be available including first aid, emergency treatment, and follow-up care as needed. All injuries will be referred to the MSU Athletic Training Staff. Payment for any further medical treatment must be provided by you and your third party payer (such as health insurance or Medicare). This does not mean that you are releasing or waiving any legal right you might have against the researcher or NDSU as a result of your participation in this research.

What if I have questions?
Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the researcher, Sam Thielen at (320) 304-4804 or samuel.thielen@ndsu.edu.

What are my rights as a research participant?
You have rights as a participant in research. If you have questions about your rights, or complaints about this research or to report a research-related injury, you may talk to the researcher or contact the NDSU Human Research Protection Program by:

- Telephone: 701.231.8995 or toll-free 1-855-800-6717
- Email: ndsu.irb@ndsu.edu
- Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: www.ndsu.edu/irb .

Documentation of Informed Consent:
You are freely making a decision whether to be in this research study. Signing this form means that

1. you have read and understood this consent form
2. you have had your questions answered, and
3. you have decided to be in the study.

You will be given a copy of this consent form to keep.

_______________________________________ ______________
Your signature Date

____
Your printed name

_______________________________________ ______________
Signature of researcher explaining study Date

Sam Thielen
____
Printed name of researcher explaining study

APPENDIX B. DATA COLLECTION SHEET

Name/Code	Age	Year	Weight	Height	Max VJ				T-Test		
	Yrs	#	Lbs.	In.	Reach	VJ1	VJ2	Change	T1	T2	Change

Name	Squat 1RM			SEBT													
Code	Pre	Post	Change	Leg in.	A1	M1	P1	L1	SUM	SCORE	A2	M2	P2	L2	SUM	SCORE	CHANGE