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Effects of Variable Resistance Training on Kinetic and Kinematic Outcomes during a Heavy Conventional Deadlift

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EFFECTS OF VARIABLE RESISTANCE TRAINING ON KINETIC & KINEMATIC OUTCOMES DURING A HEAVY CONVENTIONAL DEADLIFT EXERCISE

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EFFECTS OF VARIABLE RESISTANCE TRAINING ON KINETIC OUTCOMES DURING A HEAVY CONVENTIONAL DEADLIFT EXERCISE

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EFFECTS OF VARIABLE RESISTANCE TRAINING ON KINETIC OUTCOMES DURING A HEAVY CONVENTIONAL DEADLIFT EXERCISE

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Variable Resistance Training (VRT), loading elastic band tension on a barbell, has shown improvements in force, power, and velocity. Studied extensively in the squat and bench press, VRT is less researched in the context of the deadlift. Additionally, while no acute VRT deadlift studies exist where intensity was ≥ 90% 1-RM, some heavy VRT studies suggest that at approximately 90% 1-RM, less band tension (BT) is required to enhance force and power than seen at lower intensities in existing research. Therefore, the purpose of this study was to determine the effects of VRT on peak relative vertical ground reaction force (VGRF), average and peak velocity, and time of peak force (VGRF time), in heavy, traditional deadlifts. **METHODS:** Seven resistance trained, college-aged males were recruited for this study. Over the course of approximately eight weeks, subjects completed five training sessions including familiarization, and testing the deadlift at 90% 1-RM with no bands (NB), 10%BT, 20%BT, or 30%BT. All training sessions were performed on dual force plates and with a linear position transducer to determine kinetic and kinematic outcomes. **RESULTS:** There were significant differences between conditions for both peak [$F(3,18) = 13.607$, $p < 0.001$] and average velocity [$F(3, 18) = 14.077$, $p < 0.001$]. No significant differences were detected between conditions for peak relative VGRF [$F(3, 12) = 2.41$, $p = 0.118$], or

VGRF time [F (3, 12) = 1.843, p= 0.193]. **PRACTICAL APPLICATIONS:** The results of this study suggest velocity is improved with 20% to 30%BT when deadlifting approximately 90% 1-RM. For maximum force, traditional, NB deadlifts might be optimal considering the lack of improvement with the addition of bands. Despite the lack of significance between conditions, the large relative percent decrease in VGRF time from NB to 10%BT suggests that this small amount of BT may be advantageous for rapid force development with heavy loads.

INTRODUCTION

Force, power, and velocity are characteristics that play an integral role in the success of nearly all sports (24). Thus, the goal of resistance training for sports is to enhance force, power, and velocity. Where heavy resistance training leads to the development of slow, absolute strength, velocity is typically exploited by training with little to no load. As is such, strength & conditioning coaches and sports scientists have employed several exercises/techniques across the intensity spectrum, in an attempt to enhance these attributes, using compound lifts like the squat, bench press, and deadlift; power exercises like the clean & jerk and snatch; and ballistic training with loaded squat jumps or bench throws (1,9,11,14,18,21,22,35). However, in recent years, scientists and practitioners have taken particular interest in a training technique that may enhance force and power characteristics equal to or greater than that of traditional resistance training exercises, called variable resistance training (VRT).

VRT is a type of resistance training that involves elastic bands or iron chains attached to a barbell. Research focusing on VRT has increased recently; however, it was previously popularized in powerlifting training by Louie Simmons (29). It is suggested that VRT is used to develop maximum muscular tension in an exercise, eliminating the athlete's tendency to decelerate the barbell near the end of the lift (30). For example, at the bottom of a barbell squat, the barbell is the furthest perpendicular distance from the hips (which are acting as the fulcrum), causing the athlete to experience the "heaviest" weight of the barbell. Near the end of the concentric phase, the distance between the barbell and fulcrum gradually decreases, leading to an increase in mechanical advantage, which makes the weight feel relatively lighter. Therefore, less torque is required to complete the lift, and athletes may experience compensatory deceleration. Variable resistance training may counteract this deceleration by accommodating for the gradual increase in mechanical advantage. This accommodation occurs via a gradual increase in band tension or chain links unfurling from the floor leading to an increase in force applied to the bar throughout the concentric phase (30).

This hypothesis is supported by a number of cross-sectional studies. Both Lopez et al., 2016 and Israetel et al., 2010 reported superior power output for VRT versus load-volume equated controls, in the bench press, and squat, respectively. Where Lopez et al., 2016 found 85% 1-RM with 15% of the load as band tension improved the max accelerative portion of the bench press, Israetel et al., 2010 found that approximately 100kg of band tension accentuated force and velocity during the last 10% of the concentric phase and power during the last 10%-15% of movement completion (15,16). Galpin et al., 2015 and Scott et al., 2018 determined that deadlift VRT with bands was superior to the NB barbell and hex bar deadlifts, respectively, for enhancing power (12,26). However, deadlift VRT with chains as opposed to bands appears to blunt vertical ground reaction force, power, and velocity (20,33).

In addition to acute training sessions (12,23,33,38,40), VRT has also been studied in the context of periodized resistance-training programs (2,25,28). For the squat, intensities ranging between 67% and 98% 1-RM, with 20% to 35% of the total load as band tension, appear to positively influence jumping performance and isokinetic power (2,28). Wallace et al., 2006 examined the effects of squat VRT in men and women, at 60% or 85% 1-RM with either 20% or 35% of the total load as band tension. The authors found no significant group differences between VRT and the NB control group at 60% 1-RM, but found that at 85% 1-RM, the experimental groups displayed significantly greater force and power. In a similar squat study, Stevenson et al., 2010 found that squat VRT performed at 55% 1-RM with 20% band tension as part of the total load led to a significant decrease in concentric average velocity and peak velocity vs. the control group. This information leads the authors of the current study to believe that VRT is no more effective than traditional resistance training when performed ≤ 60% 1-RM.

Although VRT has been examined both acutely and in periodized resistance training, a gross amount of the research in this field focuses on the squat and bench press exercises (2,4,5,16,25,28,31,38,40), with less research on the deadlift exercise (12,20,26,33). Among the current deadlift VRT studies, both chains and resistance bands were utilized to apply the accommodating resistance. When chains were utilized, it was noted that load-volume equated, traditional deadlifts were superior to deadlifts utilizing VRT. Swinton et al., 2011 found an inverse relationship between chain weight, power, and velocity at intensities as low as 30% 1-RM and up to 70% 1-RM. In a later study, Nijem et al., 2016 found 85% 1-RM, with 20% of the load as chain weight, decreased vertical ground reaction force versus a load-volume equated control. While VRT with chains appears detrimental to deadlift performance, both Galpin et al., 2015 and Scott et al., 2018 observed VRT with bands had positive effects on power and velocity. Galpin et al., 2015 found that deadlifting at 85% 1-RM with 15% or 35% of the load as band tension improved peak power and velocity, while Scott et al., 2018 found VRT had the same effect on power and velocity while employing a hex-bar deadlift at 70% 1-RM and approximately 23% of the load as band tension. Therefore, it would be beneficial, when performing deadlift VRT, to utilize bands as opposed to chains. Furthermore, to the authors' knowledge, no VRT study has observed the effects of deadlifting in excess of 85% 1-RM, with the exception of Shoepe et al., 2011. In that study, intensity ranged from 67% 1-RM to 95% 1-RM, with band tension comprising between 20% to 35% of the load. However, despite including a banded deadlift in this 24-week training protocol, the only informative outcome measure was lower body strength measured using the squat (28). The only insight available for near-maximal deadlift VRT comes from a study by Paditsaeree et al., 2016 that involved a heavy clean pull, an exercise closely related to the traditional deadlift. The authors of this study employed a 90% 1-RM clean pull with either 10% or 20% band tension. The authors noted the following: 1) peak power was optimized at 10%, but declined at 20% band tension, 2) there were no differences in peak force between either band condition, and 3) peak power loss between conditions was driven by a loss in peak velocity from NB to 10% band tension, and from 10% to 20% band tension (23). These results indicate that at near maximal intensity (around 90% 1-RM), less band tension is required to enhance force and power than that observed at lower intensities, and more band tension may be non-beneficial.

The importance of studying heavy load VRT stems from the generalization that it tends to improve strength, power, and velocity beyond the capabilities of load-volume equated, traditional resistance training, regardless of whether it is carried out on the upper-body (2,4,25), or lower-body (12,31,38,40). Given this benefit, it is important to note that traditional, heavy deadlift training correlates highly with squat strength, sprint, and jump performance (17,34,39), which begs the question as to whether heavy deadlift VRT would be superior to non-VRT utilizing the deadlift exercise. Therefore, the purpose of this study was to determine the effects of VRT on peak relative vertical ground reaction force (VGRF), time of peak force (VGRF time), and peak and average velocity in a conventional deadlift exercise at 90% 1-RM with NB, 10%, 20%, or 30% band tension (BT) comprising the total load. It was hypothesized that 1) peak relative VGRF would be directly related to % band tension applied, 2) velocity would be inversely related to % band tension applied, and 3) VGRF time would be lowest in the 30%BT condition.

LITERATURE REVIEW

Traditional Resistance Training

Resistance training is well known for its role in improving athletic performance via enhancement of muscle force, power, velocity, and hypertrophy (24). Resistance training involves several modalities including weightlifting, ballistic training, and compound lifts such as the squat, bench press, and deadlift**.** There are advantages to each of these respective techniques in regard to which athletic variable they enhance, and a combination of techniques and loading strategies, with regard to specificity of sport and time of season, may help optimize performance by improving multiple athletic variables. For instance, heavy loading (between 85% 1-RM and 100%

1-RM or 1-RM to 6-RM) is necessary for improving slow, maximal strength, whereas light to moderate loads (between 0% 1-RM and 60% 1-RM), performed at explosive velocities, are necessary for improving rapid force production (24). While hypertrophy can be achieved in all loading zones, hypertrophy training without regards to strength gains should be performed with light loads and repetitions nearing, or at, failure to emphasize metabolic stress and improve local muscular endurance (27). However, it has been suggested that lifting in a repetition range between 6-RM and 12-RM (between 67% 1-RM and 85% 1-RM) may maximize the interaction between strength and hypertrophy through combined metabolic and mechanical growth factors (24).

Compound Lifting

A compound, or core lift, is one that utilizes one or more large muscle areas and involves two or more primary joints. Due to their multi-joint nature, these exercises require greater coordination than assistance exercises. Therefore, core lifts receive priority over assistance exercises during training, as the latter recruit smaller muscles and involve one primary joint.

The need for coordination and the use of multiple large muscle groups involved with core lifts may mean that exercises such as the squat, bench press, and deadlift have a greater carryover to sports, as athletic success is dictated in part by factors such as strength and coordination. In fact, squat strength is highly correlated to sprint performance at both short (9) and long distances (19), likely due to the influence that vertical ground reaction force plays in sprinting. McBride et al., 2009 investigated the relationship between squat strength and sprint times at 5yd, 10yd, and 40yd, in 17 Division-IAA male football players, and found a significant negative correlation between 1-RM squat strength and 40yd sprint time ($p < 0.01$, $r = -0.6048$), and 10yd split ($r = -0.5437$), but did not find any correlation between squat strength and the 5yd split. Additionally, participants that had a 1-RM ≥ 2.1x body weight had significantly decreased 40yd sprint and 10yd split times vs. those who squatted ≤ 1.9x bodyweight. Comfort et al., 2012 performed a similar study on 24 professional rugby and 20 recreationally trained athletes. Like McBride et al., 2009, the authors of this study found that in both groups, 1-RM squat strength was related to mid to long distance sprint performance in the 10m and 20m sprints. The rugby athlete group had significantly decreased sprint times at both 10m ($p < 0.003$) and 20m ($p = 0.005$), compared to the trained control group. However, there were significant strength effects for the recreationally trained group (10m sprint $p = 0.003$, $r = -0.621$; 20m sprint $p = 0.005$, $r = - 0.604$), but non-significant effects for the same sprints in the professional rugby group, which led the authors to note that though squat strength is important in sprinting, strength may greater aid untrained and recreationally trained individuals during sprint performance, whereas well-trained athletes are more likely to improve their sprinting performance from an enhancement in running mechanics.

Unlike McBride et al., 2009, Comfort et al., 2012 found that when the data from this study was combined, there was a significant correlation between squat strength and 5m sprint performance, in addition to sprint performance at longer intervals, lending evidence to the value of squatting strength in both early phase acceleration, and long-distance sprinting (up to 40yd). While greater absolute squat strength appears to improve sprint performance, relative strength ≥ 2.1x body weight seems to improve performance beyond what is noted in individuals that squat below this relative strength threshold.

The results of the aforementioned studies are further validated by several resistance-training studies focusing on periodized upper and lower body training. Chelly et al., 2009 investigated the effects of two months of squat training, between 70% and 90% 1-RM, in 22 male soccer players (age= 17yr, ± 0.3yr). Outcome variables were cycle power, 1-RM strength, and running velocities during a 40m sprint split into two sections: 1) the first step up to 5m and 2) between 5m and 40m. The authors of the study determined that, compared to the control group (n=11), the squat training group significantly improved cycle power at all friction loads (ranging from 2.5% to 11.5% body mass), 1-RM squat strength ($p = 0.001$), and running velocity during the initial phase of acceleration ($p < 0.05$) as well as during late phase sprinting ($p < 0.05$) (7).

Other full-body training programs have led to the general improvement of performance in both 1-RM strength and isokinetic strength; however, improvements in power were not noted (1,14). Gorostiaga et al., 1999 conducted a study that observed the effects of a six-weeks training program including the bench press, squat, leg curl, leg press, and Pec Dec machine, on strength (1-RM and isometric), and explosive upper/lower body power in 24 youth handball players (age range = 14 to 16yr). After six weeks, the authors concluded that the heavy resistance-training group (n=9) had significantly greater 1-RM strength in the Pec Dec ($p < 0.01$) and leg press ($p < 0.01$), and greater isometric flexion/extension strength ($p < 0.05$ and $p < 0.01$, respectively) than both the handball (n=10) and control groups (n=5).

In a later study, Andersen et al., 2005 observed the effects of a three-month training program including the incline press, hacksquat, leg curl, and leg extension exercises on isokinetic leg extension strength and power in 14 untrained males (age = 23.6 ± 3.1 yr). After three months of training, the authors observed a significant increase in isokinetic strength at both 30 (18% increase, $p < 0.01$) and 240 (10% increase, $p < 0.05$) degrees/sec in the experimental group (n=14), compared to the control group (n=10).

For both Gorostiaga et al., 1999 and Andersen et al., 2005, strength improved from several weeks of resistance training, but not lower body power. Gorostiaga et al., 1999 used a protocol of 40% 1-RM x12 repetitions, 50% 1-RM x10 repetitions, 80% 1-RM x 6 repetitions, and 90% x 3 repetitions for each exercise trained, while Andersen et al., 2005 used an average load between 6-RM and 12-RM (67% 1-RM to 85% 1-RM). With load volume in mind, it makes sense that the respective authors noticed an improvement in slow strength, but not power, as loads between 0% 1-RM and 60% 1-RM performed at a quick velocity are typically used to enhance muscular power, whereas loads between 67% 1-RM to 85% 1-RM, and up to 90% 1-RM, are used to enhance muscular hypertrophy and strength (24). Despite the lack of improvement in lower body power, Gorostiaga et al., 1999 observed that the resistance-training group enhanced upper body power as measured by an improvement in pre-to-post handball throwing velocity ($p < 0.01$). There is no way to determine the exact cause of this improvement, due to the full-body nature of the training program and the numerous factors involved in throwing velocity. However, since both authors failed to improve lower body power using these full-body training regimens, this improvement likely occurred because of improved upper body strength, lower body strength, throwing mechanics, or a combination of these factors.

Weightlifting

Weightlifting traditionally refers to the following two movements: 1) clean & jerk and 2) snatch. However, weightlifting derivatives are variations of these two movements and include, but are not limited to, power cleans, where the weight is received in a quarter- to half-squat position, hang variations where the barbell begins somewhere above floor, and high pulls where the catch phase is excluded from the exercise (37). Weightlifting, and its derivatives, are widely used in strength and conditioning programs to develop muscular power, or to enhance performance in sprinting, jumping, and agility drills (21,22,35), as these movements involve moving a relatively heavy load a long distance in a short amount of time. Evidence exists that weightlifting may enhance jumping performance better than jump training, as well as improve sprinting performance (35); however, Oranchuk et al., 2017 noted that weightlifting and jump training resulted in similar improvements in jumping performance. Lastly, weightlifting training may have a carry-over in power to activities with dissimilar movement patterns, such as the club head speed during a golf swing (22).

Tricoli et al., 2005 compared a periodized weightlifting program, including the clean high pull, power clean, and clean & jerk, to a vertical jumping program, including drop jumps, and one/two-legged hurdle hops, to determine the effects on countermovement jump (CMJ) and squat jump (SJ) height, and time performance in both a 10 m sprint and agility drill. Additionally, both groups performed strength training in the half squat exercise and a 1-RM test for this exercise was also conducted. Over the course of an eight-week experimental period, the authors found that SJ and 10m-sprint time were improved in only the weightlifting group. While both groups improved CMJ height, the weightlifting group improved significantly more than the vertical jump group. The improvements for the weightlifting group in SJ, 10 m sprint, and CMJ are likely due to an improved rate of force development due to the nature of weightlifting, where heavy loads must be moved with high velocity. However, the authors also noted that while both groups improved 1-RM strength in the half squat, the vertical jump group improved more than the weightlifting group. Despite this, and considering the faster 10 m sprint time elicited by the weightlifting group, it can be assumed that the improvement in rate of force development played an important role in improving athletic performance, more so than absolute strength.

In a similar eight-week study by Oranchuk et al., 2018, the authors had collegiate golfers perform a strength/power training program, including the power clean, squat, and deadlift, or a program consisting of low-load rotational exercises specific to the sport of golf. The aim of this study was to examine the effects of these programs on club head speed, peak and average CMJ height, as well as 1-RM strength in the power clean, squat and deadlift. After an eight-week experimental period, the strength/power group significantly improved performance on all dependent variables, except peak club head speed. No significant improvements occurred in the rotational exercise group; however, this group exhibited a significant decrease in performance, as the average club head speed decreased in the group after training. The results of this study parallel those of Tricoli et al., 2005, where the proposed improvement in rate of force development from performing power movements led to a sport-specific performance improvement. In the case of Oranchuk et al., 2018, strength/power training improved club head speed where golf-specific rotational exercises did not; Tricoli et al., 2005 saw an improvement in two different jump tests for weightlifting over jump-specific training. Based on these studies, there appears to be a carry-over effect from performing weightlifting movements and derivatives on sport-specific activities, such as jumping, sprinting, and even club head speed in a golf swing.

Contrary to the aforementioned studies, jump training, compared to weightlifting training, has been shown to be equally effective for improving RFD, CMJ and JS peak power, and isometric force during a mid-thigh rack pull/isometric hold (Oranchuk et al., 2017). However, the authors of this study compared the hang clean high pull performed at 70% 1-RM power clean and trap bar jumps at 20% of trap bar deadlift 1-RM. This difference is unique, as the previously mentioned studies performed weightlifting movements including the catch phase and un-weighted jumps (21,35). It is plausible that the equivalent performance across groups in this study is due to the unique exercise prescription of 70% 1-RM in the weightlifting group and 20% 1-RM in the jumping group. Previous studies found 20% 1-RM optimal for power performance in trap bar jumps (36) and 70% 1-RM optimal for power performance in the power clean/clean high pull (10,32). As both groups used what was considered by the authors to be an optimal intensity for power production in each respective exercise, a lack of significant differences between groups is not surprising.

Ballistic Training

Ballistic training is a popular training method used to improve explosive power. Ballistic training is designed to enhance the accelerative phase of a movement, while minimizing deceleration, by either throwing an implement (bench throws), or jumping with weights (squat jumps). It has been noted that ballistic training may enhance lower body power to a greater degree than traditional lower body exercise (11,18) and that a cluster-set protocol can further accentuate velocity (3).

While performing ballistic training alone can lead to performance improvements, even further benefits occur when ballistic and strength training are combined. Cormie et al., 2007 compared seven sets of six jumps at bodyweight (ballistic group) to five sets of six bodyweight jumps with the addition of three sets of three repetitions of the squat at 90%1-RM (ballistic + strength group). The group that did a combination of ballistic and strength training improved their vertical jump power at bodyweight, 20kg, 40kg, and 60kg, while the ballistic group improved jump power at bodyweight, 20, and 40kg only. These results suggest that heavy resistance training with combined ballistics may provide the necessary stimulus to increase ground reaction forces for jumping, beyond that of ballistic training alone.

Heavy squat jumps may also improve the initial accelerative phase of sprinting more than light squat jumps. McBride et al., 2002 compared volume-equated heavy and light squat jump training (80% 1-RM vs. 30%1-RM) on performance in the pro-agility drill and 20 m shuttle run. The authors found that test performance improved in both groups, pre-to-post, with the lighter group improving more than the heavy jump group. However, the heavy squat jump group had a significantly higher velocity during the initial 10 m of the 20 m shuttle. The authors noted that heavy jumps are effective in improving initial acceleration when movement velocity is slow, but light jumps improve acceleration during higher velocity movements (18).

Lastly, there is evidence to suggest that repetition movement velocity in ballistic training is enhanced by cluster set training. Artacho et al., 2018 compared six continuous repetitions of squat jumps (traditional group) with six repetitions of squat jumps with 30 seconds of rest between every two repetitions (cluster group), over six power training sessions. Loading for both groups was 20% 1RM of the back squat exercise. The authors determined that the cluster protocol was superior for preserving velocity, as there was a significant percent loss in velocity over the course of the set in the traditional jump squat group, but not the cluster set group. Additionally, the cluster group significantly improved jumping power, compared to the traditional group, during a jump test at 25% and 75% body mass. This difference occurred due to a moderate and small increase in velocity at 25% and 75% body mass. This velocity improvement for the cluster group is likely due to the recovery/preservation of the pCr system, which in turn allowed this group to produce more explosive jumps, leading to higher velocities when jumping.

Variable Resistance Training (VRT)

Variable resistance training (VRT) is a form of resistance training that utilizes elastic bands and/or iron chains attached to a barbell. While VRT is an emerging interest in strength and conditioning research, the use of VRT has been popularized for years in the sport of powerlifting, especially by Louie Simmons (29). It is suggested that variable resistance is used to develop maximal muscular tension throughout the entire concentric portion of the lift, eliminating the athlete's tendency to decelerate the barbell near the end range of motion, typical of traditional resistance training (30). For example, at the bottom of a barbell squat, the barbell is at its furthest perpendicular distance from the hips (acting as the fulcrum), causing the athlete to experience the "heaviest" weight of the barbell. As the lift nears completion, the distance between the barbell and the fulcrum continues to decrease, as mechanical advantage of the muscle increases, making the weight feel relatively lighter; in turn, less force is required to complete the lift, and athletes may experience compensatory deceleration. Bands and/or chains may solve this problem by accommodating for the gradual increase in mechanical advantage, by generating more force throughout the concentric phase via a gradual increase in band tension, or chain links unfurling on the floor (30).

VRT Squat

The traditional, barbell squat is a staple in strength and conditioning programs for its ability to enhance athletic performance via strength carryover for sports (24). Several authors provide evidence that using variable resistance training (VRT) with the squat exercise can enhance force, power, and velocity, which include VRT used during periodized resistance training studies (2,28) and studying the acute effects of VRT (31,38,40). The VRT utilized in these studies was delivered via band tension, not chain weight. Anderson et al., 2008 studied the squat as part of a seven-week training program in 44 NCAA Division I athletes (age= 20 ± 1 yr) from sports including men's and women's basketball, wrestling, and women's hockey. The athletes trained in a daily-undulating (DUP) fashion with intensity prescribed between 72%-98% 1-RM with 20% of the total load coming from band tension (2). In a similar DUP study of 24 weeks, Shoepe et al., 2011 examined the effects of band tension on the squat in a group of 20 novice lifters (age = 20 ± 1.4 yr) training between 67%-95% 1-RM with a range of 20%-35% of the total load coming from band tension (28). Participants from both respective studies improved strength; however, where Anderson et al., 2008 reported significantly greater improvements than the no band (NB) control group (+16% vs. +6%), Shoepe et al., 2011 reported improvements in both the experimental and NB control groups, with no differences between groups from 12 to 24 weeks (28). Additionally, Anderson et al., 2008 observed that squat VRT improved average power during a vertical jump test, which was supported by Shoepe et al., 2011 who found that the VRT group displayed significantly greater power at 330°/sec, compared to the NB control group.

While improvements in power are meaningful, especially with regard to squat VRT transferring to sport performance, these improvements do not indicate if rate of force development improves due to squat VRT. As rate of force development is important to sports performance, this question is important to answer. Similar to Shoepe et al., 2011, Wyland et al., 2015 examined the effects of squat VRT, performed at 85% 1-RM with 30% band tension as part of the total load, in 20 recreationally active males (age = 23.3 ± 4.4 years). The authors found that VRT, like previous studies, improved squat 1-RM in the experimental group compared to the NB group. Additionally, the experimental group improved rate of force development during a vertical jump test and decreased sprint time during a 9.1 m sprint. The improvement in sprinting performance could be due to the enhanced rate of force development observed during the vertical jump test. This inference is probable considering the important role that vertical ground reaction force plays in sprinting (9,19).

Based on the previously noted literature, squat VRT appears to be effective at intensities ranging between 67%-98% 1-RM (2,28), with band tension ranging between 20%-35% of the total load (2,28,40). However, both Wallace et al., 2006 and Stevenson et al., 2010 determined that squat VRT does not always result in positive outcomes. Wallace et al., 2006 found that in a group of 10 individuals (men: n = 6, age = 21.7 ± 1.8 years; women: n = 4, age= 20.8 ± 1.0 years), with six months of squat training, smith machine squat VRT did not result in differences between the experimental group and the control group for peak power or peak force at 60% 1-RM, with either 20% or 35% band tension as part of the total load. Similar to other studies, Wallace et al., 2006 found that squat VRT at 85% 1-RM produced significant differences between groups; which led the authors to note the following: 1) there appears to be a direct relationship between the amount of band tension on the bar and peak force and 2) peak power appears to improve with the addition of band tension, but peaks at 20% of the total load (38). Stevenson et al., 2010 studied the squat at 55% 1-RM with 20% band tension as part of the total load and found that VRT led to a decrease in concentric average velocity and peak velocity, compared to the NB control group. Interestingly, Stevenson et al., 2010 investigated 22 males with resistance training experience (resistance training= 10.4 ± 4.7 years) men. When looking at the results of these studies together, it appears that squat VRT may be ineffective at low intensities, irrespective of training age.

VRT Bench Press

The traditional, barbell bench press is a staple in several strength and conditioning programs for its ability to improve upper body strength for carryover for sports (24) and has also been studied in the context of VRT, with both band tension and chain weight. While no known studies have examined force directly, several studies have examined the effects of VRT on 1-RM bench press strength (2,5,25,28). Bellar et al., 2011 examined the effects of band tension on 1-RM bench press strength in a group of 11 untrained, college-aged men (age= 23.6yr, ± 3.2yr). To control for neural adaptations in these untrained participants, the authors employed three weeks of traditional free weight training before testing 1-RM strength, and then tested 1-RM strength again following three weeks of VRT, or NB training for the control group. The authors found that training with a load of 85% 1-RM with 15% of the total load as band tension, for five sets of five repetitions led to a significant increase in bench press 1-RM (mass= 100.0 kg, ± 18.9 kg pre; mass=109.9 kg, ±19.4 kg post) vs. the NB control group (mass=101.5 kg, ± 19.6 kg pre; mass= 109.0 kg, ±20.3 kg post) which trained with 85% 1-RM without band tension (5).

A similar study by Shoepe et al., 2011 examined the effects of band tension on bench press 1-RM strength in 20 novice lifters (age= 20.0yr, ± 1.4yr) over a large loading range, 67% 1-RM and 95% 1-RM, with band tension held constant at 20% to 35% of the total load. After 24 weeks of daily undulating style periodized (DUP) VRT, with volume equated across groups, the NB free weight group significantly improved bench press 1-RM, yet, bench press 1-RM was not different between groups, suggesting that VRT is a suitable alternative to traditional resistance training for novice lifters. Although the bench press 1-RM was measured in this study, measurements of velocity and power were not collected. It is plausible that the VRT group, despite the lack of difference in 1-RM strength, was more powerful than the free weight group at post-test, due to increases in bar velocity during the lift. This hypothesis may be due to the kinetic nature of bands, which stretch as the lift progresses through the concentric phase, forcing the lifter to apply more force near the top end range-of-motion.

These results are similar to those in a later study by Lopez et al., 2016 which examined the effects of band tension on repetitions to failure, peak velocity, and the max accelerative portion of the bench press in eight professional, male rugby players (age= 27yr, ± 4.15yr) and eight resistance trained participants (age= 20.86yr, ± 1.35yr). The authors found that VRT at 85%

1-RM with 15% of the total load as band tension did not lead to significant differences in repetitions to failure, but accentuated the peak accelerative portion of the bench press in both professional athletes, as well as the resistance trained group. These acceleration improvements were not demonstrated in the control group. Only the professional rugby players significantly improved peak velocity, implicating that VRT may hold special uses for advanced athletic populations (16).

There is other evidence to support the efficacy of VRT for trained athletes. A study by Anderson et al., 2008 examined the effects of band tension on bench press 1-RM strength in 44 Division I athletes (age= 20.0yr, ± 1yr), from sports including men and women's basketball, wrestling, and women's hockey. After seven weeks of DUP training, including the bench press performed at intensities between 72% to 98% 1-RM, with 20% of the total load provided from band tension, the authors determined that the experimental group significantly improved their 1-RM strength (+8%) over the NB control group (+4%) (2). Riviere et al., 2017 reported similar findings in a study involving 16 elite youth rugby athletes (age= 17.8yr, ± 0.9yr). Similar to Anderson et al., 2008 methodology, they employed a six-week DUP training protocol utilizing intensities between 70% to 92% 1-RM, with 20% of the total load provided from band tension, compared to a NB control. After the training period, the authors determined that the VRT group significantly improved bench press 1-RM over the NB group, and displayed medium to very large improvements in power and velocity when assessed at 65% 1-RM, 75% 1-RM, and 85% 1-RM. (ES range = 0.34 to 1.44). The NB group elicited only trivial to small improvements in power and velocity (ES range = 0.13 to 0.38) (25).

These power and velocity results agree with Baker et al., 2009, investigation of thirteen professional rugby players. The participants had moderate VRT experience and performed the bench press at 75% 1-RM with 15% of the total load coming from chain weight rather than band tension. The authors determined that VRT with chains improved average velocity and peak velocity during the concentric portion, and peak velocity during the eccentric portion of the bench press, compared to the control group (4). While this study is the only one reviewed involving chain use during the bench press exercise, it provides initial evidence that both band tension and chain weight, within the context of VRT, are effective at improving bench press performance.

As a whole, VRT bench press appears to be more effective than traditional bench press with free weights when the intensity/volume is equated, at enhancing force via 1-RM strength (2,5,25,28), bench press power (25), and velocity using chains (4) and bands (16, 25).

VRT Deadlift

The traditional, barbell deadlift is a staple in several strength and conditioning programs for its ability to improve lower body strength for carryover for sports (24) and has also been studied in the context of VRT, with both band tension and chain weight. Galpin et al., 2015 measured the effects of band tension on a barbell deadlift in twelve resistance trained (6 months, 1x/week VRT experience) males and found a direct correlation between the amount of band tension applied (up to 35% band tension) and peak velocity, average velocity, peak power, and average power, at both 60% 1-RM and 85% 1-RM (12). In a similar study by Scott et al., 2018, the authors examined the effects of VRT with the hex-bar deadlift, at 70% 1-RM with 23% of the total load as band tension, on a pre-post counter-movement jump (CMJ) in university level rugby players. The authors found that the VRT group improved CMJ height, peak power, peak velocity at peak power, and vertical GRF, compared to the control group (NB) (26). While the deadlift appears to benefit from VRT with bands, the evidence regarding the effectiveness of VRT with chains in the deadlift exercise is more difficult to understand. Swinton et al., 2010 observed the effects of chain weight on a barbell deadlift in rugby players (n=8) and powerlifters (n=15) at 30%, 50%, and 70% 1-RM. The authors found that both power and velocity decreased at all loads from NC to 20% of the total load in chain weight, and again from 20% chain weight to 40% chain weight. However, the authors found a positive relationship between force, impulse, and chain weight at all loads (33). Lastly, Nijem et al., 2016 investigated the effect of chain weight on the barbell deadlift in a group of men with a minimum of six months deadlifting experience. The authors noted that the VRT group (85% 1-RM, with 20% of the total load as chain weight) produced less vertical ground reaction force and no change in rate of force development, compared to the control group (NC) (20).

When performing deadlift VRT, training with bands appears superior to training with chains. The former is evidenced as effective for both the barbell (12) and hex-bar variations (26) while enhancing vertical ground reaction force, power, velocity, and CMJ, while the latter leads to reductions in power, velocity, and vertical ground reaction force (20,33). However, when training specifically away from the high velocity side of the force-velocity curve, chains may be of benefit, especially in a sport such as Powerlifting, where slow velocity and high force and impulse play much greater roles, as opposed to sports that require greater rate of force development such as sprinting, football, basketball, and wrestling (33).

VRT Weightlifting

Traditional weightlifting, or power exercises have been used in strength and conditioning programs to enhance rate of force development and power, by moving moderate to heavy loads, quickly (24). VRT has been applied to weightlifting variants such as the snatch, clean, & clean pull, with both band tension and chain weight, to mixed results. In one such study, Coker et al., 2006 studied the snatch of seven elite regional or national level competitive weightlifters, using 80% or 85% 1-RM. The VRT groups had 5% of their total load as chains in both experimental groups, where the control group (NC) lifted either 80% or 85% 1-RM without chains. The authors found no significant differences in vertical GRF, max bar velocity, or RFD between the experimental groups and the control groups (NC) (8). In a similar study by Berning et al., 2008, the authors compared the clean of seven elite weightlifters at intensities of 80% and 85% 1-RM with chains, compared to control groups (NC). Similar to Coker et al., 2006, the authors of this study found no significant group differences for vertical GRF, max bar velocity, or RFD (6). However, despite the lack of kinetic differences in these studies, both Coker et al., 2006 and Berning et al., 2008 found that VRT applied to weightlifting movements was perceived by the lifters as more difficult than traditional weightlifting (6,8).

In contrast to the two previous studies mentioned, Paditsaeree et al., 2016 studied the effects of band tension on the clean pull of six elite female weightlifters. Intensity was set at 90% 1-RM with either 10% band tension or 20% band tension as part of the total load. The control group (NB) lifted at 90% 1-RM without bands. The authors noted the following, 1) peak force increased from NB to 10% band tension, but the force displayed at 20% band tension, was not significantly different from 10% band tension, 2) peak power improved from NB to 10% band tension, and decreased from 10% to 20% band tension, and 3) velocity had an inverse relationship with the amount of band tension applied to the load.

It appears that VRT is ineffective at enhancing performance in weightlifting, at least with chains. In the case of Coker et al., 2006 and Berning et al., 2008, the amount of chain weight utilized did not elicit any kinetic or kinematic changes measured; however, the chains did appear to have an effect on the lifter perceptually, which could imply that mechanical adaptations are occurring. This finding raises the question as to whether a greater chain load could potentially lead to force, power, rate of force development, and velocity enhancements. For Paditsaeree et al., 2016, 10% band tension was enough to enhance the clean pull. However, there appears to be a small range within which VRT training with bands becomes advantageous during weightlifting movements. Force and power production improve with 10% band tension as part of the total load, but a further increase in band tension leads to a decrease in force, power, and velocity.

SUMMARY

Traditionally, compound lifts such as the squat, bench press, and deadlift, power exercises such as the clean and jerk and snatch, and ballistic exercises like the squat jump or bench throw have been used to improve athletic performance via enhancement of a combination of strength, power, and velocity. Although VRT, using band tension or chain weight to influence the load on the bar, is a fairly novel technique, there is evidence that this type of training leads to improved athletic performance beyond that of traditional lifting, when volume and intensity are equated. VRT with bands and chains enables the lifter to enhance the accelerative properties of the lift, especially near the end of the concentric phase of lifting where participants tend to decelerate along with an increase in the mechanical advantage of the muscle. For this reason, VRT may be a viable training alternative, especially with compound lifts, which tend to improve slow strength, but not explosive strength. By using band tension or chain weight as part of the load, VRT theoretically enables the lifter to enhance both slow and explosive strength at once, as the total system weight increases throughout the lift as chain weight unfurls on the ground or band tension increases.

METHODS

Experimental Approach to the Problem

A randomized, repeated measures design was employed in this study to compare the deadlift with and without band tension (NB) as part of the total load, in trained college-aged males. Data collection took place over an eight-week period and five sessions, with an individual session taking place every 48 to 72 hours, at the discretion of the participant. The first session was used to determine deadlift 1-RM and for band familiarization. Sessions two through five were used to determine the effects of NB and barbell loads with 10%, 20%, or 30% of the total load as band tension on relative peak vertical ground reaction force (VGRF), time of peak VGRF (VGRF time), average velocity, and peak velocity. The load for all conditions was approximately

90% 1-RM at lockout. Measurements were collected utilizing two force plates (Advanced Mechanical Technology, Inc., Watertown MA, USA) and a linear position transducer (Model Openbarbell v3, Squats and Science, Brooklyn, NY, USA). In order to determine the length-tension relationship of the bands, a band was anchored across the platform and stretched at the center with a hanging hook scale (Model ES-PS01, Dr. Meter) to 14 different heights ranging from 10.8 to 109.6 cm, in 7.6 cm increments, identical to those used by Galpin et al., 2015. Bands were anchored to the floor around the force plates with four 0.5 x 2.54 cm steel eyelets and four 0.5 x 5 cm steel carabiners, one per corner, spaced out to the specifications of a 2.5 x 1.2 m deadlift platform (Rogue Fitness, Columbus, OH, USA). The feedback from the hook scale was used in conjunction with subject lockout height to determine the appropriate combination of bands to provide the correct lockout tension.

Participants

Seven resistance trained (≥ 1 year of deadlift experience), college-aged males (ht: 171.71 ± 5.5 cm; mass= 82.4 ± 10.9 kg; deadlift 1-RM: 182.14 kg ± 30.86 kg) from the university campus were recruited to participate in this study. All participants reported high experience (> one year) with free weight resistance exercise, including the deadlift, and no experience with VRT in the year prior to the study. No participants reported using anabolic steroids, and all participants were free of any current or previous musculoskeletal injury that would prevent them from performing the deadlift with correct technique.

Training sessions lasted approximately 60 minutes and were conducted by a Certified Strength and Conditioning Specialist (NSCA-CSCS). Participants were not asked to refrain from their normal training, eating, or drinking habits outside of the study.

Before data collection, participants were informed of the risks associated with heavy resistance training and provided written informed consent. This research project was approved for the use of human participants by the university Institutional Review Board.

Procedures

Data collection occurred over a total of eight weeks and across five sessions per participant, with an individual trial taking place every 48 to 72 hours. Session one consisted of a five-minute warm-up on the treadmill at a self-selected pace, followed by a deadlift warm-up described by Galpin et al., 2015. Briefly, the following was performed: ten repetitions at 50% 1-RM, five at 70% 1-RM, and one repetition at an estimated 90% 1-RM, with three minutes rest between sets. Participants were then given up to five single attempts to determine a 1-RM, with five minutes rest between sets. A 1-RM attempt was considered successful when the participant lifted the barbell with a neutral spine and stood with the knees and hips in full extension. No assistance gear (i.e., lifting straps, belts) was permitted during any session, but participants were permitted to use an alternated or double-overhand grip. Immediately following 1-RM testing, bands were attached to the barbell for familiarization, which consisted of three sets of one repetition at 50% of 1-RM with the Openbarbell attached to the bar. The Openbarbell range of motion function was used during familiarization to determine lockout height (cm). The lockout height recorded was the average height of three repetitions. This value was used to determine the appropriate combination of bands and free weight for a given participant during data collection trials.

Following 1-RM testing and familiarization, participants performed sessions two through five in a randomized fashion, which consisted of three sets of three repetitions at 90% 1-RM with either no bands, 10% band tension, 20% band tension, or 30% band tension as part of the total load. The volume-load for this study was set at 90% 1-RM, as it equates to an approximate 4-RM (24). Therefore, with adequate rest between sets, 90% 1-RM would provide a challenge, but would be an appropriate load prescription. The warm-up procedures during sessions two through five consisted of a five-minute walk on a treadmill at a self-selected pace, followed by a deadlift warm-up with one set of ten repetitions at 50% 1-RM, one set of five repetitions at 70% 1-RM, and three repetitions at 80% 1-RM. All warm-up sets were separated by three minutes of rest.

Data Analysis

Peak relative VGRF and time of peak VGRF (VGRF time) were recorded during sessions two through five using two force platforms. Only the second repetitions in a set were chosen for analysis, as the authors believed this would reflect the most valid repetition, as it receives a potentiation effect from the previous eccentric contraction, but does not have as much accumulated fatigue behind it as the third repetition. Additionally, only the third set of each session was used for final analysis of peak relative VGRF, and VGRF time, as this set contained the greatest number of reliable trials across all conditions. In total, there were 20 sets analyzed for peak relative VGRF, and VGRF time. Peak and average velocity were measured using a linear position transducer, Openbarbell, which was previously validated against the Optotrak Certus 3D motion capture system. The Optotrak is considered the "gold standard" for research scientists. The Openbarbell device demonstrated concurrent validity compared to the Optotrak, for average velocity (13). Due to the high validity of the Openbarbell in comparison to the Optotrak, average and peak velocity values were reported as the mean of all nine repetitions in each condition.

Statistics

The data was statistically analyzed using a one-way ANOVA with repeated measures, with each session (NB, 10%BT, 20%BT, 30%BT) used as the repeated measure. This statistical analysis was run for each dependent variable, as it was assumed that the dependent variables were not correlated. Mauchly's test for sphericity was interpreted for each analysis before interpreting the test for main effects. If a significant difference for the main effect was observed, post-hoc analyses were interpreted to determine differences between specific loading conditions, utilizing a Bonferroni correction for multiple comparisons. An alpha level of 0.05 was used to determine statistical differences between conditions.

RESULTS

Velocity

Significant differences existed between conditions for both peak velocity [F (3,18) = 13.607, p < 0.001] and average velocity [F (3, 18) = 14.077, p < 0.001]. According to the post hoc tests, significant differences occurred between the NB and 20% BT conditions (peak velocity p = 0.018; average velocity p= 0.037), NB and 30% BT conditions (peak velocity p= 0.042; average velocity p= 0.023), and 10% BT and 30% BT conditions (peak velocity p= 0.023; average velocity p= 0.027) (Figure 1).

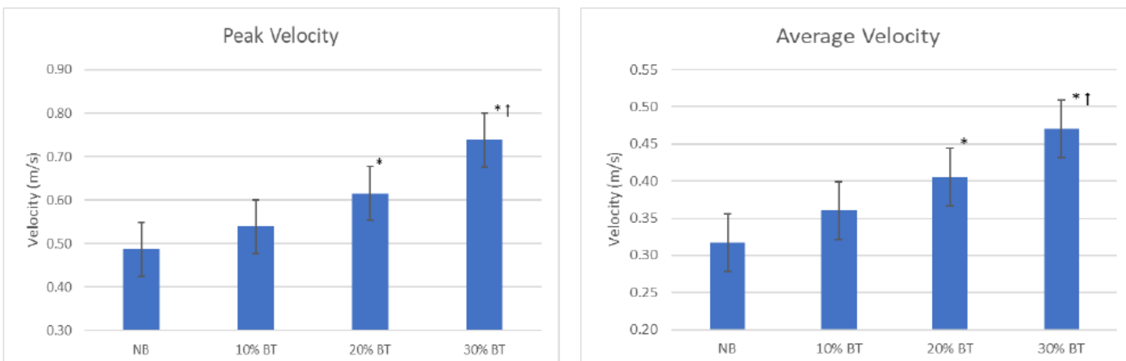

Figure 1. Graphical representation of the results for peak and average velocity. *Denotes significantly greater mean velocity values vs. NB. ƗDenotes significantly greater mean velocity values vs. 10%BT. (p ≤ 0.05). NB= No bands, 10%BT= 10% band tension, 20%BT= 20% band tension, 30%BT= 30% band tension

Force & Timing Characteristics

There were no significant differences between conditions for peak relative VGRF [F (3, 12) = 2.41, p= 0.118], or VGRF time [F (3, 12) = 1.843, p= 0.193] (Figure 2).

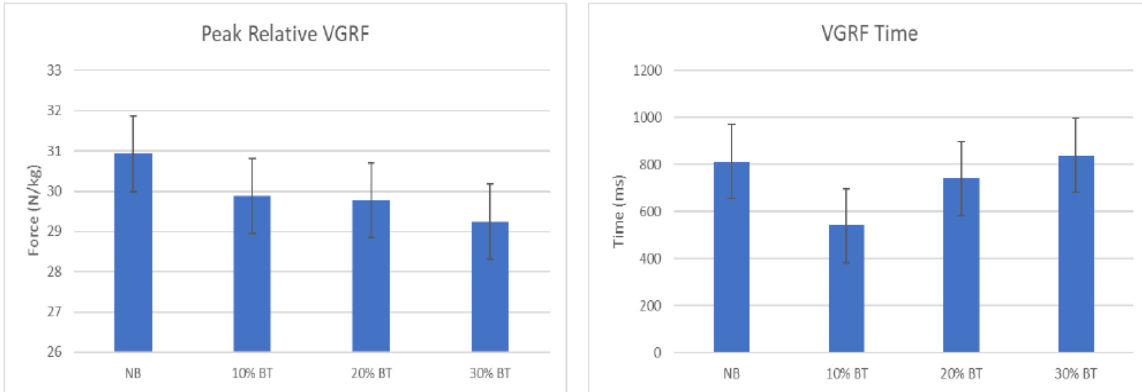

Figure 2. Graphical representation of the results for peak relative VGRF and VGRF time. ($p \leq 0.05$). NB = No Bands, 10%BT= 10% band tension, 20%BT= 20% band tension, 30%BT= 30% band tension

DISCUSSION

The purpose of this study was to determine the effects of VRT on peak relative VGRF, VGRF time, and peak and average velocity in a conventional deadlift exercise with and without band tension at 90% 1-RM. It was hypothesized that 1) peak relative VGRF would be directly related to the percentage load of band tension applied to the barbell, 2) peak and average velocity would be inversely related to the percentage load of band tension, and 3) VGRF time would be lowest in the 30%BT condition.

The results of this study do not support our first hypothesis. While band tension appeared to have an inverse relationship with peak relative VGRF, there were no statistically significant group differences in VGRF between NB and any of the experimental conditions. The lack of significance between conditions may, in part, be attributed to the range-of-motion of the deadlift with the combined influence of band tension. Since the deadlift has a small range of motion, and the band tension did not begin to impact the lift until the barbell was close to knee height, peak relative VGRF was not different between conditions. These results are similar to those of Paditsaeree et al., 2016 where force was not significantly different between 10% and 20% band tension in a 90% 1-RM clean pull. However, it should be noted that the authors did find significant differences between traditional clean pulls and VRT clean pulls (23).

It was also hypothesized that peak and average velocity would be inversely related to the percentage load of band tension. Our results do not support this hypothesis, as additional band tension seemed to increase peak and average velocity. Velocity percent differences between conditions were as follows: from NB to 10%BT velocity increased by 10.2% for peak and 12.5% for average, from 10%BT to 20%BT velocity increased by 14.81% for peak and 13.89% for average, and from 20%BT to 30%BT velocity increased by 19.35% for peak and 14.63% for average. However, these increases in velocity were not significant between adjacent conditions. Compared to NB, 10%BT did not significantly enhance velocity, but 20%BT was significantly faster than NB (peak= 26.4%; average= 28.06%). Similarly, 30%BT was not significantly faster than 20%BT, but was significantly faster than 10%BT (peak= 41.06%; average= 34.72%). The greatest, statistically significant increase was from NB to 30%BT (peak= 51.63%; average= 48.36%).

Although the current findings for velocity did not support our hypothesis, they are comparable to the outcomes of other deadlift VRT studies using lower relative intensities. Similar to the current study, Scott et al., 2018 found an increase in velocity at peak power in both a squat and hex-bar deadlift at 70% 1-RM with approximately 23%BT, and Galpin et al., 2015 found both peak and average velocity increased at 85% 1-RM when additional band tension was factored into the absolute load (35%BT > 15%BT > NB) (12,26). Contrarily, Paditsaeree et al., 2016 found an inverse relationship between band tension and velocity during a heavy clean pull (23). These results are also noted in other weightlifting VRT studies in which small amounts of variable resistance lead to power and velocity attenuation (6,8). It should be noted that a clean pull is a weightlifting exercise that is technique-intensive and requires high levels of coordination, thus any additional novelties, including variable resistance, would likely result in performance reductions. Furthermore, it is plausible that stretching VRT bands at a rapid rate results in a higher resistance force than when these band are elongated at a slower rate.

Concerning VGRF time, the results of this study do not support our hypothesis, as no significant group differences were observed for this variable. Despite the lack of statistically significant findings, there are some findings worthy of noting. Compared to the NB condition, the relatively small amount of band tension applied during the 10%BT condition resulted in a 33.58% decrease in VGRF time, while the 20%BT condition only decreased VGRF time by 8.98%. Another interesting finding occurred during the 30%BT condition, where VGRF time increased by 3.2%, compared to the NB condition. Although the percent change from NB to 10%BT was relatively large, it is possible that the lack of statistical significance is driven partly by a small sample size. It stands to reason that at 90% 1-RM, 10%BT may provide a "sweet spot" by which a smaller amount of variable resistance, than previously seen in research, improves VGRF time. At this high prescribed intensity, 20%BT or 30%BT of the total load may leave too much of the total system resistance as variable resistance, which likely negatively influences lifting mechanics. As previously stated, the bands do not influence the pull until the bar is close to knee height, and in the case of the 20%BT and 30%BT conditions, this characteristic of VRT would not leave enough plate resistance at the start of the pull to reach peak VGRF earlier in the movement.

These results are not in line with the work of Galpin et al., 2015 who found that at an intensity of 85% 1-RM, 35%BT, but not 15%BT, was significantly different in time of peak force, with the decrease in time of peak force favoring the 35%BT condition (12). In the current study, the large, albeit non-significant, percentage decrease in VGRF time from NB to 10%BT may show how greater absolute loads differ from lighter loads during VRT, but especially deadlift VRT. When comparing Galpin et al., 2015 research conducted at 85% 1-RM to the current study at 90%1-RM, our 5% difference in intensity found an insignificant, 3.2% difference between NB and 30%BT conditions by which 30%BT slightly increased VGRF time. Additionally, our results may differ due to training status. In both studies, subjects were considered resistance trained; however, the current study required subjects to have participated in no VRT training for one year prior to the study, whereas Galpin et al., 2015 required that subjects had performed VRT training at least once per week during the previous six months. It is possible that the participants in the current study did not experience any significant enhancement in VGRF time because they had not trained long enough with VRT to experience the benefit from this type of training.

While this study revealed fascinating information, especially concerning velocity, it has limitations. One limitation to this study is the sample size. However, the study recruited experienced, resistance trained participants, specifically those with deadlift experience. Additionally, participants needed to be willing to undergo strenuous testing, consisting of a high-intensity, multi-set protocol. Accordingly, large participant turnout was not expected. Furthermore, this study was limited to male participants only in order to control for factors that may be influenced by sex. The sample size problem may have been mitigated by including both male and female participants.

In summary, this study showed that deadlifting at 90% 1-RM with 20%BT or 30%BT as part of the absolute load significantly improved peak and average velocity vs. a NB load-volume equated control. However, the 20%BT and 30%BT were not significantly different from each other. Therefore, when training with 90% 1-RM for velocity, it is beneficial to use between 20% and 30% BT. Additionally, though peak relative VGRF was not significantly different between conditions, there appeared to be an inverse relationship between peak relative VGRF and the amount of band tension on the bar, where 30%BT produced the lowest VGRF. Therefore, when absolute strength and force production are the goals, these might be best improved with traditional, NB deadlifts. Lastly, though no significant differences were obtained, there was a 33.58% decrease in VGRF time from NB to 10% BT, which was larger than the percent changes from NB to 20% BT (-8.98%), and NB to 30%BT (3.2%). This trend might suggest that when trying to attain peak VGRF quicker, that a small amount of band tension, i.e., 10%, may be most effective.

This study investigated the acute effects of high intensity deadlift VRT. As is such, future research should investigate several combinations of band tension in long-term, and periodized studies. Additionally, future studies should include powerlifters, and the sumo deadlift, as VRT is anecdotally popular in the sport of powerlifting and the sumo deadlift is an often-used style by powerlifters. Furthermore, resistance trained, and untrained females, female powerlifters, and other female sport athletes should be included in future research samples.

CONCLUSIONS

This study has demonstrated the effects of heavy deadlift VRT on peak relative VGRF, average and peak velocity, and VGRF time in resistance trained males. The results of this study suggest that coaches and athletes looking to improve velocity during deadlifts at 90% 1-RM should employ between 20%BT and 30%BT. As for force accentuation, traditional NB deadlifting might be most effective, and for VGRF time, using 10%BT might prove optimal. According to the results of this study, it is important that sport coaches and athletes determine the specific training goal and employ appropriate band tension, or lack thereof, to meet that training goal.

It should be noted that athletes who are not familiar with VRT should first familiarize themselves with light resistance in both absolute intensity and percent BT. More importantly, athletes should be supervised by a coach, experienced in using VRT, especially when lifting with heavy loads and relatively large amounts of BT.

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FIGURE LEGENDS

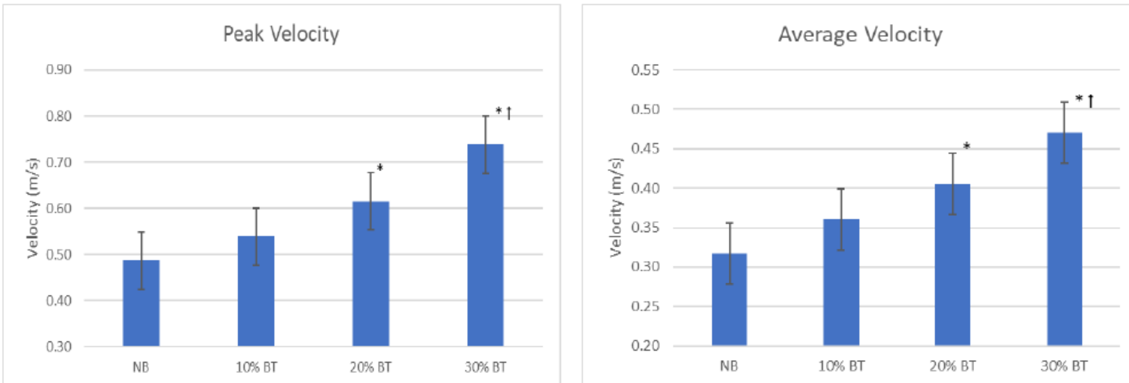

Figure 1. Graphical representation of the results for peak and average velocity. *Denotes significantly greater mean velocity values vs. NB. ƗDenotes significantly greater mean velocity values vs. 10%BT. ($p \leq 0.05$). NB= No bands, 10%BT= 10% band tension, 20%BT= 20% band tension, 30%BT= 30% band tension

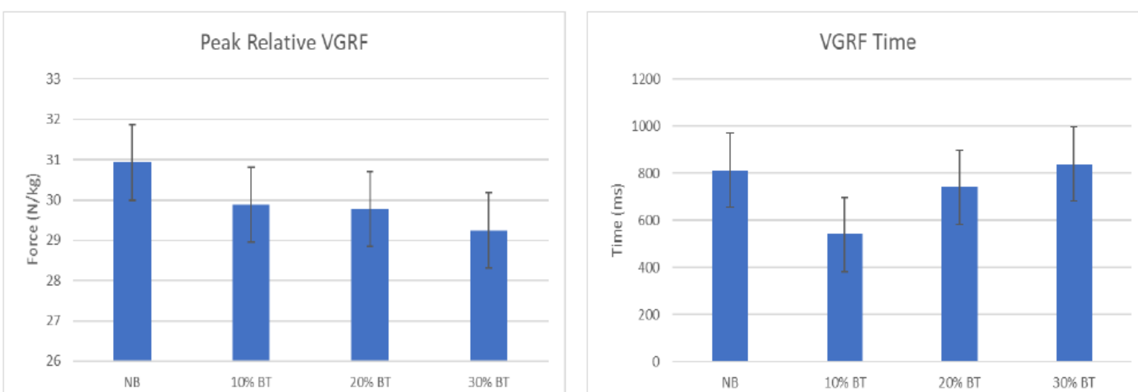

Figure 2. Graphical representation of the results for peak relative VGRF and VGRF time. ($p \leq 0.05$). NB = No Bands, 10%BT= 10% band tension, 20%BT= 20% band tension, 30%BT= 30% band tension