THE EFFECTS OF ACCENTUATED ECCENTRIC LOADING SCHEMES ON CONCENTRIC POWER OUTPUT DURING THE BACK SQUAT PERFORMED BY RESISTANCE TRAINED MEN

By

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A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of Master of Science in Exercise Science
to the office of Graduate and Extended Studies of
East Stroudsburg University of Pennsylvania

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ABSTRACT

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Exercise Science to the Office of Graduate and Extended Studies of East Stroudsburg University of Pennsylvania

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Title: The Effects Of Accentuated Eccentric Loading Schemes On Concentric Power Output During The Back Squat Performed By Resistance Trained Men

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Abstract

Previous research has indicated that resistance training utilizing accentuated eccentric loading patterns augments concentric outputs. Mechanical stretch coupled with eccentric overload may potentiate the concentric phase of the back squat. Therefore, it is important to understand the various mechanisms involved and their potential relation to increased concentric back squat performance. **Purpose:** The aim of the study was to examine the differences in power output in college aged resistance trained males performing traditional and AEL back squats. **Subjects:** Eight male volunteers (N= 8) agreed to participate in the present study (age: 23.8 ± 1.6 years, mass: 84.3 ± 11.7 kg, height: 174 ± 9 cm). All subjects had previous experience in resistance training and were free from musculoskeletal injuries for up to one year. The subjects were asked to complete three experimental conditions during which kinetic data was collected. The three conditions were: Traditional (80/80% 1RM), AEL1 (105/80% 1RM), AEL2 (110/80% 1RM). Two repetitions were performed for each condition. Average power output was collected immediately following each repetition during the back squat. **Results**: The results showed a significant difference ($p = 0.002$) between the conditions. There was a significant ($p = 0.009$) decrease in average power output from the AEL2 condition compared to the traditional and AEL1 condition. **Conclusion:** Utilizing AEL patterns did not have any advantage over traditional loading patterns in terms of enhancing average power production. The eccentric overload prescribed in the AEL2 condition may have been too much for the current population noted by the decrease in performance. Future research is warranted on finding the optimal eccentric load to enhance concentric performance.

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CHAPTER 1
INTRODUCTION

Incorporating resistance training as part of an individual's overall fitness program is a proactive measure in preventing numerous diseases and physical ailments associated with aging, and it has been shown to sustain quality of life by restoring functional capacity (Feigenbaum, 1999). Resistance training is particularly important to the athletic population for increasing performance and preventing injuries. Athletic populations use resistance training to improve muscular strength, size, power, speed, endurance, balance, and coordination (Kraemer, 2000). Enhancing these skill related components of fitness is necessary to carry out the motor performance skills required for optimal athletic performance (William, Nicholas, Duncan, 2002).

Skeletal muscle adaptations occur specifically to the mode and intensity of exercise (Coffey and Hawley, 2007). The frequency of training is equally as important in driving long-term adaptations. Skeletal muscle seems to be responsive to a mechanical stretch along the sarcolemma and is considered the primary mechanism for exercise-induced adaptations (Coffey and Hawley, 2007). Mechanical stretch coupled with overload is shown to be the most effective method to induce skeletal muscle adaptations by adding sarcomeres in parallel and in series (Goldspink, 1999).

Improving athletic performance becomes more challenging as training experience increases. Therefore, other methods such as accentuated eccentric loading techniques have been used to further elicit neuromuscular adaptations (Walker et. al, 2016). There are various mechanisms responsible for the augmentation of concentric performance during accentuated eccentric loading (AEL). Increases in concentric performance can be attributed to the enhancement of the SSC by the eccentric overload (Doan et. al, 2002). The manipulation of eccentric loads to enhance maximum concentric force production is said to be responsible through various mechanisms involving increased neural stimulation, recovery of stored elastic energy, mechanical alterations, and increased preload. (Ojasto and Hakkinen, 2009). Ojasto and Hakkinen (2009) found that utilizing AEL techniques generates larger concentric power outputs than traditional training methods while performing the bench press exercise.

It has been demonstrated that approximately 120% of concentric muscle actions are produced by eccentric muscle actions (Munger et. al, 2017). This may then suggest that traditional styles of training under load the eccentric phase limiting concentric performance. This type of training is most applicable to athletes who perform various multi-joint exercises that involve large muscle groups with the purpose of enhancing power output or RFD (Munger et. al, 2017.) Doan and associates (2008) state that increased eccentric loading is beneficial to induce acute increases in concentric strength. Acute increases may depend on the current level of training the athlete possesses.

Multiple studies have been done utilizing accentuated eccentric methods during multi-joint movements. AEL patterns involve an eccentric overload phase followed by a lower loaded concentric phase of a repetition (Ojasto and Hakkinen, 2009). A study done by Ojasto and Hakkinen (2009) compared traditional loading patterns to dynamic accentuated external resistance loading (DAER) techniques performed on the bench press and examined the effects on acute neuromuscular, maximal force, and power responses. The authors concluded based upon their findings that there were no changes in the maximum strength group performing DAER loads of 105, 110, 120% of 1RM for the eccentric phase. In fact, utilizing these techniques revealed lower concentric force values in the (105/100%, 110/100% and 120/100%) conditions compared to the control group (100/100%) (Ojasto and Hakkinen, 2009). This may imply that utilizing DAER techniques with eccentric and concentric loads of this magnitude may not be beneficial to improving maximum concentric strength. It was concluded that the traditional explosive strength group did produce higher concentric peak power values for each individual in the 77.3 ± 3.2/50% from the control condition (50/50%) (Ojasto and Hakkinen, 2009). This may imply that optimal loading should be individualized when using DAER techniques when aiming to increase concentric power production (Ojasto and Hakkinen, 2009). Walker and associates (2016) looked at AEL compared to traditional isoinertial loading using the leg press in already strength-trained men.

These researchers found that accentuated eccentric techniques led to greater strength gains, work capacity, and muscle activation (Walker et al., 2016). However, the increases in muscle activation can be underpinned by the muscle damaging effects of eccentric training and diminished concentric EMG amplitudes as a result of altered motor unit recruitment and synchronization (Walker et. al, 2016). Different responses to eccentric and concentric outputs may occur during AEL loading and AEL cluster sets (Wagle et. al, 2018). The use of adding rest periods between each repetition when performing AEL patterns is thought to be more beneficial for maximizing concentric power output and RFD by reducing fatigue. Therefore, higher power outputs can be maintained throughout repetitions because of less metabolite accumulation (Wagle et. al, 2018). Employing short rest periods between each repetition for the subjects is likely to provide even more relevant data because of the ability to setup for the next repetition with readiness, which may demonstrate more accurate differences in average power output between AEL conditions. Previous research has shown that overloading the eccentric component of the back squat when performing clusters displayed negative effects on peak power and concentric work (Wagle et. al, 2018). A possible explanation for these findings is the programming of 3 sets of 5 repetitions being too much volume inducing fatigue. Previous literature has studied the potentiating effects of AEL techniques on concentric outputs but little attention has been given applying it to the back squat. Furthermore, the research that has been done looking at AEL techniques used loads and repetition schemes that didn't produce any meaningful results in concentric power outputs. Performing AEL back squats with heavier eccentric loading and less volume could possibly provide more applicable data because of the increased preload necessary for the musculature involved and alterations in volume to reduce fatigue. The current study used eccentric loads of greater magnitude for the subjects performing AEL back squats and performed only two repetitions of each condition with 30 seconds interrepetition rest in theory of inducing acute concentric potentiation while avoiding metabolic fatigue.

Purpose

The purpose of the study was to examine the differences in power output in resistance trained males performing traditional and AEL back squats.

Null Hypothesis

(There will be no difference in concentric power output in individuals performing accentuated eccentric loaded back squats with 105/80% 1RM compared to traditional loading patterns with 80/80% 1 RM.)

(There will be no differences in concentric power output in individuals performing accentuated eccentric loaded back squats with 110/80% 1RM compared to traditional loading patterns.)

Operational Definitions

For the purpose of this present study the following operational definitions applied:

1.) Resistance trained males- The subjects have 6 months or more of resistance training experience

2.) Traditional Loading- eccentric and concentric loads are equated to 80% 1 RM.

3.) Accentuated Eccentric Loading – The subjects perform ECC loads of 105 and 110% 1RM followed by CON loads of 80% 1RM.

4.) Kinetic responses- Average power output during the concentric phase using a Linear Positions transducer

5.) Stretch-Shortening Cycle- the transition time between the eccentric and concentric phase

6.) Series Elastic Component (SEC)- containing fiber-cross bridges, aponeurosis, and tendon

Limitations

For the purpose of this present study the following limitations applied:

1.) Level of adherence to pre-test conditions due to not having the ability to monitor subjects outside of the testing time.

2.) Load knowledge testing may not demonstrate true maximal effort.

3.) Biomechanical differences between the subjects may impact the results.

Delimitations

1) Male subjects who are resistance trained for 6 months or more

2) Free from any musculoskeletal injuries for 1 year or more

3) Students from East Stroudsburg University

Summary

Previous research has indicated that resistance training that utilizes AEL patterns produces higher power outputs throughout the concentric portion of the exercise being performed. Some of the past literature has examined alterations in power output in the bench and leg press. Some of the findings concluded that utilizing AEL patterns throughout both exercises increased maximal force production and peak power outputs. Previous research has examined AEL patterns with emphasis on greater eccentric loads compared to concentric loads, however much of the studies done used concentric loads that were ineffective for increasing concentric power output limiting the outcome of the data.

CHAPTER 2
LITERATURE REVIEW

The purpose of the study was to examine the differences in power output in resistance trained males performing traditional and AEL back squats. The following chapter will present a review of the literature for the following: eccentric training, neural adaptations, storage and utilization of elastic energy, stretch reflex, alterations in contractile machinery, and enhancing stretch-shortening capabilities.

Eccentric Training

The eccentric portion of a muscle contraction occurs when a muscle is forced to lengthen as a result of being placed under a load. The structural damage that occurs to muscle fibers when the loaded muscle is forcibly lengthened ultimately leads to a disruption of the sarcomeres within the myofibrils (Proske and Morgan, 2001). The sarcomeres become disrupted in series as a result of being overstretched and eventually with enough structural damage to the muscle membrane a new optimal length for tension will develop (Proske and Morgan, 2001). It is postulated that after eccentric exercise, the non-uniformity of the sarcomeres creates a fall in active tension creating a shift in the muscles optimum length for active tension

(Proske and Morgan, 2001). Although, metabolic factors such as diminished excitation-contraction coupling process could be a possible mechanism for a fall in active tension (Proske and Morgan, 2001). It is stated that the primary mechanism behind skeletal muscle adaptations to eccentric exercise is based on the addition of sarcomeres to restore muscle fibers and what drives the damage to the muscle is dependent on sarcomere length (Proske and Morgan, 2001). The properties of eccentric training and its effects on skeletal muscle provide an effective way to maximize force while serving as a protective mechanism for athletes against injury.

Previous research has proven that the amount of force produced by eccentric muscle actions is 20-60% greater than concentric actions (Mike et. al, 2017). The eccentric phase of a muscle contraction in considered more beneficial than the concentric phase at inducing hypertrophy in type IIx skeletal muscle (Walker et al., 2016). The eccentric phase has been shown to produce more damage to the muscle fibers being trained. Studies have proven that more tension is generated when muscle fibers are being lengthened than when being shortened and with less metabolic cost (Lorenz and Ramen, 2011). Previous research has shown that muscles being lengthened eccentrically require less muscle activation and less fiber recruitment to produce a given force (Lorenz and Ramen, 2011). Therefore, during an eccentric contraction less metabolic waste is produced as a result of diminished ATP utilization compared to the concentric phase (Lorenz and Ramen, 2011).

Neural Adaptations

Strength training stresses the central nervous system and can elicit neural adaptations throughout skeletal muscle. As a result, chronic training adaptations lead to increased force production. When training at high intensities, the CNS regulates force production either by recruiting more motor units or increasing motor unit firing frequency (Hedayatpour and Falla, 2015; Bradenburg and Docherty, 2002). However, force production capabilities are often limited by incomplete activation of motor unit recruitment or firing frequency (Gabriel, Kamen, and Frost, 2006).

Overloading the eccentric phase of a muscle action may increase motor unit firing frequency and improve concentric front squat performance (Munger et. al, 2017). These researchers found that concentric peak velocity and peak power significantly increased in the heaviest AEL condition. They suggest that eccentric overload may provide the stimulus needed to increase the rate of motor unit discharge during the concentric phase enabling an individual to produce a higher RFD. Gabriel and associates (2006) state that increased motor unit firing may be responsible for rapid increases in force production at the onset of strength training. Significant increases in voluntary activation of the quadriceps' was discovered when performing AEL for 10 weeks of bilateral leg press and knee extension exercises measured by twitch interpolation techniques performing maximal isometric contractions (Walker et al., 2016). Altered calcium levels can also be responsible for increased voluntary activation, which was not accounted for in the study (Walker et. al, 2016). Twitch interpolation techniques add a stimulus to voluntary contracting muscle to observe for any increases in force production as a result of activating muscles not previously involved (Gabriel, Kamen, and Frost, 2006). These researchers suggest that no differences in cross-sectional area or EMG amplitude with concomitant increases in strength provide evidence of neural enhancement.

Specific tension significantly increased 22% in the elbow extensors of subjects performing AEL techniques pre to post training (Brandenburg and Docherty, 2002). These researchers suggest neural mechanisms can be responsible for the increases in specific tension due to subject unfamiliarity with the extensor exercise chosen. Specifically, reductions in the co-activation of the antagonist muscle enables the agonist muscle to be activated more effectively leading to enhanced force production in the intended direction of movement (Brandenburg and Docherty, 2002; Aagaard et al., 2000). However, Brandenburg and Docherty (2002) found significant increases in specific tension at week 9 indicating more time might be needed to elicit this type of neural adaptation.

Maximal motor unit firing rates decreased after 8 weeks of strength training in both trained and untrained legs demonstrated by significant decreases in hamstring co activation with no concomitant change in quadriceps EMG activity (Carolan and Cafarelli, 1992). These results are in conjunction with previous research indicating that initially strength related gains can be attributable to increased motor neuron firing rates but after a period of time reduced co activation of the antagonist might be more responsible (Brandenburg and Docherty, 2002; Gabriel, Kamen, and Frost, 2006). The pre-stretch may cause an increase in neural drive that occurs during the eccentric phase of a movement creating a potentiating effect and enabling more motor units to be recruited for the concentric phase (Comyns and Flanagan., 2008). The same level of pre-activation has been demonstrated when performing a depth jump as the drop height increases. However, ground contact times must be short as well in order to get the full potentiating effect.

Storage and Utilization of Elastic Energy

Mechanical work is stored as potential energy in the series elastic component (SEC) when the active MTU is stretched (Cormie, McGuigan, and Newton (2011). This energy is said to be stored mainly in the tendon, which contains nonlinear elastic properties (Kurokawa et. al, 2003). Potential energy stored during the pre stretch of a SSC movement can then be reutilized in the form of mechanical energy throughout the concentric phase and contribute to positive work. Ojasto and Hakkinen (2009) suggest that increases in eccentric EMG activity with a concomitant increase in power production when performing AEL bench press actions may be attributable to the elastic component. Individuals with higher levels of training might be able to return more stored elastic energy through the early concentric phase when using greater AEL. The optimal use of elastic strain energy may be dependent on the concept of resonance suggesting that the frequency of the SSC movement should match the frequency of the MTU (Walshe, Wilson, and Ettema, 1998). Kurokawa and associates (2003) demonstrated rapid shortening of the muscle tendon complex by 5.3% of its original length during upward phase II from (-100 to 0 ms) before takeoff during a CMJ. These researchers stated that the energy during Phase II at toe off was released at a higher rate than it was absorbed. It is possible that at this moment in time the rate of extension matched the frequency of the MTU.

Timing of the eccentric portion of a muscle contraction can also have further implications on increased strength and power for athletic populations. A previous study has shown that performing eccentric contractions of 2, 4, and 6 seconds in duration of barbell smith machine squats at 80-85% 1RM showed increases in average power production across all 3 groups from baseline to post test jump squat protocols (Mike et al., 2017). However peak velocity in the 6-second group performing jump squats decreased (Mike et al., 2017). Possible mechanisms underpinning the decrease in peak velocity throughout the jump squats protocols have to do with the SSC. An explanation for this occurrence is the ineffective timing between the eccentric and concentric phase of the jump limiting the force generating capabilities of the musculotendinous unit (Mike et al., 2017). The ability of the elastic component of the MTU to return the energy absorbed may have been comprised and lost as heat in the group performing 6 second eccentric contractions during the jump squat protocol (Mike et al., 2017). It takes time during the eccentric phase for the agonist muscle to generate a reasonable amount of force before the concentric phase begins (Cormie, McGuigan, and Newton., 2011). However, too much time to develop force can cause power outputs to decrease. Mike and associates (2017) proved that the optimal duration for carrying out an eccentric contraction in the barbell smith squat was 2 seconds in regards to increasing vertical jump height which may have to due with the principle of specificity. Specificity of training should be similar in the movement pattern and duration of contraction of a given task for optimal transfer of an adaptation. The groups that held their contractions for 4 and 6 seconds did not demonstrate any significant differences in vertical jump height (Mike et al., 2017). The 6-second group showed a significant decrease in peak velocity after performing jump squat protocols with 45% 1RM. A possible explanation for the decrease in peak velocity could be due to the duration of the eccentric phase not being specific enough to the duration of eccentric phase involved when performing a vertical jump.

The Stretch Reflex

Doan and associates (2002) state a possible explanation for increases in concentric force after performing AEL bench press movements may be the activation of the muscle spindle, signaling more motor units to be recruited or increasing their firing rate. A potential mechanism that may augment power production in movements involving the SSC is the activation of spinal reflexes (Cormie et. al, 2011). During an eccentric contraction muscle spindles located in the intrafusal fibers of a muscle are activated by deformation stimulating *α*-motorneurons. The *α*-motorneurons activate agonist muscles leading to greater developments of concentric force and power production (Cormie et. al, 2011). Previous research has found that eccentric overload increases the magnitude and rate of eccentric force development, which is thought to enhance concentric force development due to a greater stretch of the MTU and activation of the muscle spindle (Wagle et. al, 2018). Muscle spindles respond to rapid changes in the length of a muscle, serving as a protective mechanism to the musculotendinous unit (Comyns and Flanagan., 2008). When an eccentric stretch is rapid enough, the muscle spindle acts as a mechanoreceptor responding to the rapid change in length by activating an opposite contraction of the agonist muscle (Comyns and Flanagan., 2008).

Producing greater concentric power outputs utilizing this mechanism of the SSC also affects the storage and return of elastic energy from the musculotendious unit. However, one thing to consider is the timing between both the eccentric and concentric phases of the movement when looking for a potentiating effect on concentric power output. The activation of the stretch reflex is important in activities such as running or hopping because of their rapid stretch and short transition times. Increased stiffness of the MTU increases the sensitivity of the muscle spindle to activate the stretch reflex (Nicol, Avela, and Komi, 2006). Transition times between an eccentric and concentric contraction is an important factor to consider when training an athlete based on the principle of specificity.

Alterations in contractile machinery

Some studies suggest mechanical alterations to the muscle-tendon complex may occur during stretch-shortening cycles. Such alterations have to do with the optimal stiffness of the SEC (Wilson, Wood, and Elliot., 1991). The muscles and tendons are what comprise the SEC. Optimal fascicle length and compliance of the tendon for a given task may aid in producing large power outputs (Kurokawa et al., 2003). Based on the force-length relationship an optimal amount of force can be produced depending on the length of the sarcomere. The more compliant the tendon the faster the shortening velocity of the concentric contraction will be accomplished by elastic recoil (Kurokawa et al., 2003). Some researchers have proposed that during certain activities involving the SSC, these alterations of the contractile machinery occur simultaneously enhancing muscular performance.

Walshe, Wilson, and Ettema (1998) found significant increases in mechanical work performed over the first 300ms of a concentric isokinetic squat preceded by isometric preload and a stretch shorten cycle. The researchers suggested that increased work output demonstrated in both conditions may indicate that greater tendinous extension took place coupled with lower shortening velocity of the contractile element contributing to enhanced force production based on the force velocity relationship. Sheppard and Young (2010) studied 14 males, highly experienced in bench throw exercises and found significant increases in barbell displacement across 3 AEL bench throw conditions compared to the equal loading condition. They noticed that peak concentric acceleration increased as the eccentric overload increased. They theorized that increases in concentric acceleration and barbell displacement were most likely due to an increased muscle contractile state.

Greater velocity and peak power was demonstrated when 16 strength trained volleyball athletes performed AEL countermovement jumps compared to body mass loaded jumps (Sheppard et. al, 2008). Sheppard and associates (2008) found no significant differences in eccentric movement velocity or countermovement depth between the two groups. The researchers suggested that the significant increases in concentric performance produced by the AEL group may be due to less myofibrillar displacement contributing to greater force production while the mass experiences greater initial acceleration during the concentric phase. However, they stated the myogenic mechanism most responsible for their observations was the increased active state of the cross bridges to accommodate the greater force demands during the accentuated eccentric loading phase. More cross bridge attachments lead to greater joint moments initially during the concentric phase of the movement (Sheppard et. al, 2008).

Another study claimed that SSC activities augment force production by which the tendinous structure produces high shortening velocities while the fascicles are operating almost isometrically at an optimal length to produce large forces (Kurokawa et al., 2003). Researchers suggested that activities such as sprinting which depend on creating large forces more rapidly rely on a stiffer musculotendious unit (Wilson, Murphy, and Pryor., 1994). However, this may only hold true if the force produced through this mechanism overcompensates for any losses in the elastic return of energy from the more compliant MTU. Wilson and associates (1994) demonstrated a relationship between a stiffer MTU, isometric, and concentric force production but none for eccentric force production. Again this indicates that a stiffer or more compliant musculotendinous system may only be beneficial depending on the type and duration of the contraction.

Enhancing SSC capabilities

The SSC capabilities of an athlete can be enhanced through plyometric training. One of the most common modalities to enhance the fast SSC and enhance concentric power output is a depth jump. An athlete performs a depth jump by dropping from a fixed height and immediately upon touchdown carries out a vertical jump as explosively as possible (Comyns and Flanagan, 2008). The purpose of a depth jump is to transfer from the eccentric component when landing to the concentric component leaving the ground as quickly as possible (Comyns and Flanagan, 2008). The quicker the exchange between each contraction the more explosive the athlete is considered. The purpose of this training method is to enhance the fast SSC by trying to achieve shorter contact times (Comyns and Flanagan, 2008). This is beneficial to an athlete required to attain maximum velocity in their movement through larger generations of power output (Comyns and Flanagan, 2008). Comyns and Flanagan (2008) have observed contact times of 0.25 and shorter and deemed it the threshold for short contact times elicited by the fast SSC. Common depth jumps performed range from 10-40cm and contact times observed could be long or short in duration depending on the power production capabilities of the athlete (Comyns and Flanagan, 2008).

Comyns and Flanagan (2008) hypothesized that there is a threshold to depth jump heights set at 50cm and above that can inhibit the fast stretch shortening cycle having a negative impact on the athlete's performance. Drop heights that are too high hinder the athlete's capabilities to transition from the eccentric to the concentric phase effectively and produce high power outputs. The mechanism said to be responsible for the reduction in power output during the concentric phase of a depth jump is the Golgi-tendon organ (GTO), (Comyns and Flanagan., 2007). The GTO is located in the extrafusal fibers of skeletal muscle serving as a protective mechanism in response to muscle tension (Comyns and Flanagan., 2007). Drop heights of 50cm or more stated by Comyns and Flanagan (2007) produce greater landing velocities and may place too much tension on the muscle activating the GTO complex. The result is an inhibitory effect on the agonist muscles while simultaneously activating the antagonist muscles causing a reduction in concentric power output.

CHAPTER 3
METHODS

The purpose of the study was to examine the differences in power output in resistance trained males performing traditional and AEL back squats. This chapter will present the following: subjects, procedures, instruments and data analysis.

Subjects

The subject group consisted of 8 college-aged resistance-trained males. Their mean age was 23.8 ± 1.6 years, body mass (84.3 ± 11.7 kg), and height (174 ± 9 cm). All subjects had previous experience in resistance training. At the time of data collection all subjects were free from musculoskeletal injuries injury for one year. Ethical approval was granted after review of the East Stroudsburg University Institutional Review Board for the Protection of Human Subjects. All subjects provided written consent after receiving verbal and written instructions, as well as the risks and benefits of the study.

Procedures

Prior to data collection all subjects were taken through a familiarization process. During this session anthropometric measurements were taken and each subject was instructed on squat depth and how the weight releasers work when performing an AEL back squat action.

Data Collection Sequence

After completing the familiarization period the subjects completed two testing sessions. The first testing session was for 1-RM assessment in the back squat. The second testing session contained a single trial of each of the 3 different loading schemes. The loading schemes were counterbalanced for each subject such that each loading scheme was performed in different order. Both sessions were conducted with a minimum of 72 hours in between to prevent fatigue. All participants were instructed to wear proper footwear for testing. Before each testing session each subject performed a standardized 10-minute warm-up protocol. The subjects performed 5 minutes of high knees, butt kicks, walking lunges, and toe touches followed by the NSCA 1 RM back squat warm-up protocol. A 2:1 tempo was established during the eccentric and concentric phase of the back squat prior to beginning each testing session. An internal knee angle of 90 degrees was used to indicate parallel for each testing session. This was achieved by using a plyometric box adjusted in height accordingly to each subject. Two spotters were present on each side of the barbell during both testing sessions to ensure the participants safety.

During the first session the subjects 1 RMs were assessed utilizing the standard NSCA 1-RM back squat protocol. The protocol consisted of 4 dynamic warm up sets to get the participants ready to complete their one repetition max (1 RM) testing.

Following the warm up the participants had up to five attempts to reach their 1 RM. Subjects 1 RM's were indicated by a barbell speed of 0.22 m/s.

During the second session the participants completed a single trial of each of the 3 different eccentric loads based on percentages of 1-RM. The eccentric loads were broken up into groups A (80%), B (105%), and C (110%). The concentric loads were made the same for each loading scheme at 80% 1 RM. Trial one was a traditional loading pattern of ECC (80%), CON (80%) of 1 RM. The experimental session (AEL) was made up of trial two and three using ECC loads of (105, 110%) and CON loads of (80%). Each subject received a demonstration utilizing the weight releasers before testing. To ensure the releasers were adjusted to the right height and working properly, each individual was instructed to perform the squat action down to the plyometric box with 10kg plates on each releaser before actual testing with heavier loads. Before each trial the subjects were instructed not to sit on the box at the end of the eccentric portion of the lift. Instead they were told to touch the box and go, being as explosive as possible throughout the concentric phase. The subjects were instructed to complete two repetitions for each condition. Thirty seconds from the first repetition was allotted to each subject to allow the spotters to replace the weight releasers back on the bar before immediately performing another repetition. The subjects were given 5 minutes of rest between each condition to allow for full recovery.

Instrumentation

The GymAware linear position transducer was used to measure the average power outputs of each subject during the concentric phase of the lift. In order to calculate average power output, the GymAware application will be downloaded on an Apple Ipad and synchronized with the transducer. This application provides settings to adjust based on body mass, barbell mass, and exercise modality. Given the previous variables the application calculated average power output during the concentric phase of the back squat.

Statistical Analysis

All statistical analyses were performed using SPSS (version 24.0 for Windows). The results were provided as mean ranks between related groups. Average power outputs from two repetitions under each condition were assessed. A non-parametric Friedman test ($p \leq 0.05$) was applied to the data for statistical significances between the group means. Also, a post hoc test was run on the data to examine where the differences occur using a Wilcoxon signed-rank test on the different combinations of related groups. To avoid systematic error, a Bonferroni-adjusted significance level ($p \leq 0.017$) was calculated and applied to the data to compensate for multiple comparisons between the groups.

CHAPTER 4
RESULTS

The purpose of the study was to examine the differences in power output in resistance trained males performing traditional and AEL back squats. The values in Table 1 show the data for mean power production under different loading conditions. The results of the Friedman test performed on the mean power output data revealed statistically significant differences in power output depending on which loading condition was used during the back squat, $\chi^2(2) = 12.250$, $p = 0.002$. Post hoc analysis with Wilcoxon signed-ranked tests was conducted with a Bonferroni correction applied, resulting in a significance level set at ($p \leq 0.017$). There were no significant differences between the loading conditions of 80/80% and 105/80% ($Z = -.707$, $p = 0.480$). However, there was a statistically significant reduction in power output in the 110/80% condition vs. the 80/80% condition ($Z = -2.598$, $p = 0.009$). Also, there was a statistically significant reduction in power output in the 110/80% condition vs. the 105/80% condition ($Z = -2.598$, $p = 0.009$).

Table 1. Mean Power (W) for Traditional (80/80%) and AEL (105/80%, 110/80%) Trials

80/80%	**1266±412**
105/80%	**1194±429**
110/80%	**1081±425**

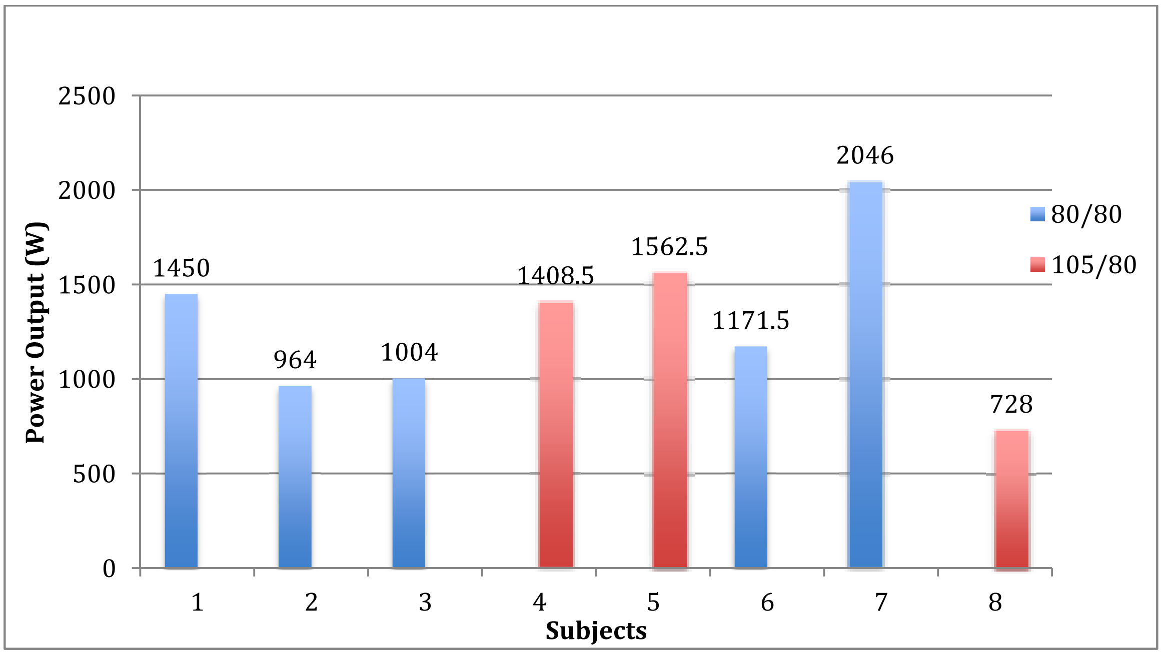

Figure 1. Individual best average power output across conditions

CHAPTER 5
DISCUSSION

The purpose of the study was to examine the differences in power output in males performing traditional and AEL back squats. Previous literature has demonstrated significant increases in individual peak and mean power production from the control of 50/50% to the AEL condition of 77.3 ± 3.2/50% (Ojasto and Hakkinen, 2009). Eccentric overload enhanced concentric power and velocity during the front squat (Munger et. al, 2017). These researchers had their subjects perform 3 different eccentric overload conditions over the course of 3 days. For the purpose of this study no significant increases in concentric power output was observed in the AEL conditions. This could be due to fatigue as a result of having the subjects complete 3 loading schemes in one testing session. Other research has demonstrated statistically greater concentric outputs utilizing accentuated eccentric cluster sets compared to traditional loading patterns not including peak power (Wagle et. al, 2018). For the purpose of this study significant decreases in mean power output were demonstrated between loading conditions. These statistical differences were present between (80/80%, 110/80%) and (105/80%, 110/80%) conditions.

In the current study no assumptions can be made in regards to AEL being more beneficial than traditional loading patterns for increasing concentric power output. This may be due to a very small sample size being used. Walker and associates (2016) found significant differences in maximum concentric force production with a sample size of 28 males. The study was also carried out over 10 weeks increasing the probability of any significant findings in their data. It has also been shown that previously resistance trained individuals performing high intensity AEL showed statistically significant improvements in repetitions to failure against concentric loads of 75% 1-RM (Walker et. al, 2016). This suggests that AEL might be a better approach to take then traditional loading patterns when it comes to completing greater workloads while minimizing fatigue. Concentric 1-RM significantly increased in a study looking at AEL in the bench press (Doan et. al, 2002). These acute increases that were demonstrated may be a result of altering the 1RM load and weight on the hooks proportionally through multiple successful attempts that were given to the subjects. The loading schemes in the current study remained the same during each attempt regardless of the subject being successful with the lift.

Performing traditionally loaded cluster set back squats produced significantly greater concentric rates of force development and average velocity compared to accentuated eccentric loaded clusters (Wagle et. al, 2018). The researchers in this study claimed that the eccentric load might not have been large enough in magnitude to induce potentiation in the concentric phase of the AEL cluster condition. Similarly, the same assumption can be made in the current study. Previous research has suggested that prescribing optimal eccentric loads when performing AEL seems to be highly individualized (Wagle et. al, 2018). However, eccentric overload was not individualized in the current study. A main effect was shown where peak velocity and peak power were greater using eccentric loads of 120% compared to 105% during AEL front squat protocols (Munger et. al, 2017). These findings contradict the results of the current study where eccentric loads of 110% significantly decreased concentric power output compared to the eccentric loads in the traditional (80%) and AEL (105%) conditions. However, the relatively small sample size and large variability between subjects in the present study should be noted.

The AEL condition (110/80%) in the current study was detrimental to concentric power production indicating this prescribed load may have been too much for this population. However, the Trad (80/80%) and AEL (105/80%) conditions showed no statistical difference in power output. It is possible that a prescribed load somewhere in between both of the AEL conditions would have shown a significant difference from the traditional loading condition. Peak displacement was greater under all AEL conditions vs. the traditional condition for males performing bench throws (Sheppard and Young, 2010). No significant differences in peak displacement occurred between AEL conditions. This indicates that although peak displacement was significantly greater for AEL's vs. the traditional condition, each individual performed best under different AEL conditions. Sheppard and Young (2010) found that the strongest athletes performed their best bench throws with eccentric loads of 74.0 ± 8.9 kg compared to the weakest athletes (62.0 ± 4.5 kg). However, the current study demonstrated that most of the subjects produced higher power outputs in the traditional vs. AEL conditions regardless of being the strongest or weakest in the back squat. Although, when instructed to touch the box and explode up some of the subjects lost their balance, coupled with a slow ascent once the weight releasers came off. This may be due to bilateral strength deficits or training history. It is also possible that the subjects did not have enough experience with AEL techniques and a longer familiarization period might have been needed.

Munger and associates (2017) stated that the magnitude of the pre stretch may have been responsible for enhanced concentric peak power and peak velocity. Performing front squats with AEL of 120% 1RM while activating the stretch reflex was proven to be effective in producing higher concentric outputs (Munger et. al, 2017). Eccentric loads of this magnitude may have been responsible for the observed differences in peak power by increasing the velocity of stretch. However, an eccentric tempo was set at 3 seconds by a metronome controlling the rate of descent. Mike and associates (2017) found significant differences in vertical jump height after 4-weeks of subjects performing 2 second eccentrics with submaximal loads in the squat. These findings imply that eccentric contractions shorter in duration may increase power output. For the purpose of this study the subjects were told to descend on a 2 second tempo and come up from the box as explosively as possible. This prescribed eccentric duration was considered adequate given the magnitude of the eccentric loads. The larger power outputs expressed during the traditional loading condition might have been due to the subjects descending at higher rates than in the AEL conditions.

Sheppard and Young (2010) state that two components that enhance the pre stretch during a stretch cycling activity are the magnitude and rate of stretch. However, no differences in eccentric depth or eccentric velocity were present but significant differences in barbell displacement were demonstrated (Sheppard and Young, 2010). Eccentric velocity during the countermovement across conditions was not recorded in the current study. Eccentric overload great enough in magnitude may recruit larger motor units and increase motor unit firing rates improving concentric performance (Munger et. al, 2017). Munger and associates (2017) found that concentric peak velocity and peak power significantly increased from eccentric overload of 105 to 120% 1RM. In the present study, concentric power output decreased for all subjects in the AEL (110/80%) condition. In this case, co-activation of the antagonist might have overridden any advantages elicited by the recruiting of larger motor units or increased rates of firing. Enhanced concentric power outputs were demonstrated in the AEL (105/80%) condition by some of the subjects in the current study. It is possible that 105% of 1RM was the optimal eccentric overload for some of the subjects to recruit larger motor units and have them stay activated during the concentric phase increasing the velocity of contraction. This implies that eccentric overload may need to be individualized to benefit from AEL.

The fact that myoelectric responses using EMG weren't accounted for in this study might limit any kind of assumptions that can be made about possible contributions from reflexive mechanisms. Therefor, increases or decreases in muscle activation patterns in each individual between conditions weren't examined. Performing jumps with a pre stretch may lead to higher jumps caused by the rapid stretch of the intrafusal muscle fibers and excitatory response of the a-afferent (Walshe, Wilson, and Ettema, 1998). The use of EMG detects differences in muscle activation patterns that may be due to *a*-afferent activation. Walshe and associates (1998) reported no significant differences in muscular activation across SSC, concentric only, or isometric preloaded squat conditions. Type Ib afferent motor neurons from the golgi tendon organ may be responsible for decreased motor unit firing rates during 120% of 3RM eccentric overload contractions (Balshaw et. al, 2017). These findings suggest that eccentric loads great enough in magnitude might activate the GTO effecting concentric performance. It is possible that this mechanism was responsible for the significant decreases in power output in the AEL (110/80%) condition as a result of autogenic inhibition. The contribution of EMG data can further give a better understanding if an individual is GTO dominant by what's going on with antagonistic muscles at different levels of eccentric loading. Inferences can also be made from this type of data on what types of training athletes should adopt to improve mechanisms that will override the GTO. The training history of the subjects in the current study was not known.

A previous study demonstrated that acquired forces in excess of 1000 N at the onset of shortening recorded by force plate data during a SSC and isometric preload vs. concentric only smith machine squat resulted in more work in the first 200 ms (Walshe, Wilson, and Ettema, 1998). Other potential mechanisms for these observed outcomes by Wilson and associates (1998) may be due to increased active state of the muscle, storage and return of strain potential energy, and the interaction of the muscle-tendon complex. However, these researchers ruled out the elastic recoil of the series elastic component as a possible contributor to the increased work because of little difference in mean transitional force between the SSC and isometric preload conditions. The current study did not include the use of a force plate. Therefor, it can't be determined which one of these mechanisms is more responsible than the other.

It is stated that when a musculotendinous units natural frequency is in sync with the activity being performed using the SSC it is in resonance (Walshe, Wilson, and Ettema, 1998). These researchers claim that the increased work over time initially in the SSC vs. isometric preload condition may have been because of the optimal timing of the extension. The timing of the eccentric phase was not tightly controlled in the current study. It is possible that some of the subjects did not descend at their elastics systems preferred rate of stretch throughout the AEL conditions. This may be the reason for significant decreases in power output demonstrated in the AEL (110/80%) condition. Without force plate data in the current study to examine other kinematic characteristics involved no further assumptions can be made as to why each of the subjects power outputs increased or decreased across conditions.

Varying levels of musculotendinous stiffness between subjects might explain differences in power output among trials in the current study. Wilson, Murphy, and Pryor (1995) state that performing an eccentric contraction with a stiffer MTU is thought to be disadvantageous due to the stretching of the contractile element past its optimal length hindering its force production. If a muscle is stretched to far it reduces the overlap between actin and myosin thereby limiting concentric force production.

Depending on the magnitude of contraction, increases in the length of the contractile element of the stiffer MTU could be detrimental to force production (Wilson, Murphy, and Pryor 1994). For the purpose of the current study all subjects performed the back squat to a plyometric box indicating a 90-degree internal knee angle. However, the results by Wilson and associates (1994) suggest that there may be optimal ranges of motion to enhance rate of force development in relation to MTU stiffness. These researchers had their subjects performing eccentric and concentric bench press actions at 90-degrees. A statistically significant energy difference over 0.37s of a concentric bench press action was demonstrated between subjects with a more compliant vs. stiff MTU (Wilson, Wood, and Elliot, 1991).

In the current study it can be postulated that some of the subjects performed better under the AEL (105/80%) condition as a result of a stiffer MTU achieved through strength training. Also some of the subjects may have performed better descending to a 90-degree internal knee angle because of having a stiffer MTU and this being the optimal ROM to enhance force production. The muscle spindle may have been more sensitive to stretch in some of the subjects due to a stiffer MTU and shorter ROM. The activation of more a-motor neurons in response to the stretch reflex may be the mechanism responsible for some of the increases in power output observed in the (105/80%) condition. Other individuals performed their best in the traditional loading condition possibly indicating they have a more compliant MTU. Although subjects with a more compliant MTU may need to perform AEL over a larger ROM to activate the muscle spindle or to take advantage of a larger storage and recovery of stored elastic energy. It has been demonstrated that subjects with a stiffer MTU generated a higher rate of force development and overall force during isometric and concentric vs. eccentric bench press actions (Wilson, Murphy, and Pryor, 1994).

It is worth mentioning that in this study each subject was instructed to descend to the plyometric box, touch, and immediately explode up concentrically. Concurrent with previous literature by Ojasto and Hakkinen (2009), reductions in power output were observed in the AEL (110/80%) loading condition vs. both the AEL (105/80%) and Trad (80/80%) conditions. This may indicate that this load intensity might have been too high for the subjects in this study to perform optimally. Other populations could be better adapted for loads of this magnitude depending on training history.

Conclusion

Previous literature has demonstrated differences in concentric outputs in AEL vs. traditional techniques (Ojasto and Hakkinen, 2009). However, the current study demonstrated no statistical significance between the AEL (105/80%) and traditional (80/80%) conditions. A significant decrease in power output was found from the AEL (110/80%) vs. the AEL (105/80%) and traditional (80/80%) conditions indicating that eccentric loading of this magnitude might be too high for this population. Large variability present between all the subjects suggests that prescribing a load for the eccentric phase of the AEL conditions should be based on the individual and not as a group.

Decreases in power output found as the load in the eccentric phase reached 110% of 1RM demonstrates the need for further analysis using EMG and force plate data. Loads of this magnitude might be disadvantageous to the mechanisms that augment power production. Changes in power production between the trials could be attributed to the stiffness of the MTU.

In agreement with prior literature MTU stiffness is significantly related to concentric performance (Wilson, Murphy, and Pryor, 1994). Reductions in power output were noticed for each subject in the heaviest AEL condition. This suggests that subjects may require a stiffer MTU to produce higher power outputs when performing AEL techniques with supra maximal eccentric loads. Further analysis may be necessary examining all the mechanisms responsible for enhanced concentric performance.

Practical Applications

In the current study, utilizing AEL over traditional loading techniques demonstrated no usefulness for increasing concentric power production. The study shows that the subjects may have not had the desired level of training to handle the eccentric overload in the one AEL condition that lead to decreased performance. The current data suggests that prescribing loads for the eccentric phase of AEL conditions may need to be individualized to enhance concentric power production based on the subject’s level of training and optimal stiffness. A longitudinal study may be necessary for augmenting concentric power output elicited by AEL over traditional loading techniques.

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East Stroudsburg University Institutional Review Board
Human Research Review
Protocol # ESU-IRB-017-1819

Date: **November 15, 2018**
To: **Gavin Moir and James Lemardy**
From: **Shala E. Davis, Ph.D., IRB Chair**
Proposal Title: **"The Effects on concentric Power output in college aged resistance trained males performing AEL back squats"**

Review Requested:	Exempted	Expedited **X**	Full Review
Review Approved:	Exempted	Expedited **X**	Full Review

FULL RESEARCH

___ Your full review research proposal has been approved by the University IRB (12 months). Please provide the University IRB a copy of your Final Report at the completion of your research.

___ Your full review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

___ Your full review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit.

EXEMPTED RESEARCH

___ Your exempted review research proposal has been approved by the University IRB (12 months). Please provide the University IRB a copy of your Final Report at the completion of your research.

___ Your exempted review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

___ Your exempted review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit, if appropriate.

EXPEDITED RESEARCH

__**X**__ Your expedited review research proposal has been approved by the University IRB (12months). Please provide the University IRB a copy of your Final Report at the completion of your research.

___ Your expedited review research proposal has been approved with recommendations by the University IRB. Please review recommendations provided by the reviewers and **submit necessary documentation for full approval.**

___ Your expedited review research proposal has not been approved by the University IRB. Please review recommendations provided by the reviewers and resubmit, if appropriate.

Please revise or submit the following:

Informed consent for scientific study

Title of investigation: The Effects of Accentuated Eccentric Loading Schemes on Concentric Power Output during the Back Squat Performed by Resistance Trained Men.

Principle investigator: James Lemardy

Overview of study

Accentuated eccentric loading has been used to generate increases in concentric power output when performing a variety of resistance training exercises. Linear position transducers are often used to calculate power output when performing a back squat. Despite the widespread use of this testing equipment, there is a limited amount of information pertaining to the different methods used to calculate power output. All testing will be performed on-campus at East Stroudsburg University.

Testing sessions

There will be two testing sessions during the study. Both sessions will be performed in the Undergraduate Laboratory of East Stroudsburg University. During the testing sessions you will be asked to perform four AEL back squats and 2 traditional back squats. Prior to the squats you will be taken through a standardized warm-up.

Although you will be undergoing physical testing, there is very little risk if you are a normal healthy individual. Individual information obtained from this study will remain confidential. Non-identifiable data will be used for scientific presentations and publications. You may withdraw from the study at any time. If you have any questions please ask Dr Moir before signing this consent form.

If you have any additional questions during or after the study, Dr Moir can be contacted at:

gmoir@po-box.esu.edu Tel: (570) 422 3335