VELOCITY BASED TRAINING AND CLUSTER SET APPLICATION FOR THE BACK SQUAT

By

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East Stroudsburg University of Pennsylvania

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

August 9, 2019

SIGNATURE/APPROVAL PAGE

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: Velocity Based Training and Cluster Set Application for the Back Squat

Date of Graduation: August 9, 2019

Thesis Chair: Gavin Moir, Ph.D.

Thesis Member: Shawn Munford, Ph.D.

Thesis Member: Brandon Snyder, M.S.

Abstract

Background: Velocity based training has been proposed as a method of periodization through prescription of velocities rather than loads in training. However, specific velocity ranges have not been studied for each exercise. Cluster sets serve as a form of set in which intra-set rest periods are added for acute recovery periods. The purpose of the study was to determine correlations between loads and velocities in the back squat, as well as examine differences in velocities between cluster sets and traditional sets. **Methods:** Fourteen participants completed three sessions of the back squat, including a max test and two experimental sessions including sets under different loading conditions (67%, 80%, 85%). **Results:** Trivial to moderate correlations were found when comparing loads and velocities. Significant differences in recorded velocities by set type were only found at the 67% 1RM condition. **Conclusion:** Weak correlations at any load imply the need to individualize VBT programs.

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CHAPTER 1

INTRODUCTION

Background

Velocity based training (VBT) has become a growing modality of training in recent years with the introduction of linear position transducer technology. The ability to measure barbell velocity allows for the creation and utilization of force-velocity characteristics to define and assess training parameters. VBT has been proposed as an auto-regulatory approach to training. Typically, training loads are determined using percentages of a one repetition maximum. However, this may create issues on days where an athlete is either fatigued or dealing with external stress factors which limit their ability to perform when utilizing loads prescribed as a %1RM (Bryce, 2016).

Methods such as a modified rating of perceived exertion (RPE) have been used for autoregulation, allowing load prescription to be determined as a response to how an individual feels on a given day. Previously RPE measurement has been shown to have a strong correlation with 1RM in powerlifters (Helms, 2017). However, RPE is not an objective measurement and requires an athlete to be able to accurately gauge how difficult a given workload is. VBT may be used as a form of objective autoregulation, wherein prescribing velocities allows an individual to determine workloads appropriate

for a given day. Previously, ranges of velocities have been presented to correlate to specific percentages of a one repetition maximum but there is minimal research to back up the presented numbers.

Lower body maximal force and power outputs are important for a wide variety of athletes due to rapid movements in sport such as sprinting, rapid deceleration, and jumping (Kubo, 2018). The back squat is a mainstay in periodized training programs for any sport in which training for strength and power are important (Hester, 2014). Due to the importance of rapid loading and force expression in the back squat, utilization of VBT can be an important factor for developing and manipulating load velocity characteristics to better develop an athlete. While general velocity ranges have been prescribed for VBT, there is currently no research to determine specific ranges for optimally training the back squat.

Cluster sets have been introduced as a method to further induce progressive overloads in training through adding an intra-set rest period. Cluster sets allow for manipulation of the set being performed through adjustments made to the frequency of intra-set rest, length of intra-set rest, load, and total number of repetitions (Haff, 2008). Cluster sets have been utilized to maintain acute mechanical performance while systematically overloading resistance for a given exercise. Previous research has shown their utilization to help with maintenance of kinematic variables such as force, power, and velocity by adding intra-set rest periods (Tufano, 2017). Intra-set rest periods as short as six seconds have been shown to decrease intra-set power output losses across varied light and heavy loading conditions (Garcia-Ramos, 2016). In high volume sets, increasing frequency of intra-set rest periods lead to a greater maintenance of power when compared to lower frequency rest periods (Tufano, 2016). Additionally, chronic cluster training has been shown to lead to greater increases in 1RM compared to other forms of training perhaps due to increases in time under tension and greater impulse generation (Nicholson, 2016). However, minimal research has been done to utilize cluster sets with VBT.

Purpose

The purpose of the study is to determine the validity of the relationship between prescribed velocities for a given %1RM when utilizing VBT for the back squat. In addition, the study aims to use kinematic data to assess previously shown maintenance of velocity and power output in cluster sets when compared to traditional loading conditions.

Null Hypothesis

There will be no significant difference in recorded velocities between cluster and traditional sets.

There will be no correlation between loads and velocities.

Limitations

Several limitations impacted the completion of the study. First, lack of experience with cluster sets may have had an impact on data. While the participants were all resistance trained and experienced in the back squat, they may not have had experience training with cluster sets. The position of the linear position transducer may have affected results due to its placement on the lateral end of the barbell. Any rotation of the barbell would potentially alter recorded velocities, impacting total displacement and thus velocity during a repetition.

Delimitations

Collegiate-aged males (ages: 21-23) were recruited for the study. The study required all participants to have a minimum of one-year resistance training experience with a training frequency of greater than or equal to three days per week. Participants were required to have experience in the back squat as technique was not taught during the study. While nutrition was not tracked participants were asked to maintain their normal dietary intake throughout the duration of the study. In order to prevent external fatigue adequate rest was provided between trials with a minimum of 72 hours after 1RM testing followed by 48 hours between experimental sessions. Additionally, participants were informed to avoid lower body physical activity for the duration of the study.

CHAPTER 2

LITERATURE REVIEW

Velocity Based Training

Velocity based training has many proposed benefits that have been outlined in numerous studies. The use of velocity-based training introduces a new metric to track and modify programming with. VBT may be used to identify day to day fluctuations in training (Mann, 2015). Controlling loading by recording velocities may be particularly useful a**s** changes in daily readiness have been observed through estimating 1RMs during warm up sets without interfering with daily training (Jovanovic, 2014).

When arranging data across loads and matching with RIR, previous studies have shown similar velocity decrements in the smith-machine half squat while approaching failure. This has very significant implications in training if it is assumed an athlete is exerting maximal effort, it is possible to reliably track how many repetitions they can complete before reaching failure. (Jovanovic, 2014.). Movement velocities may be used to determine the level of effort during different resistance exercises. A study examining the bench press, full squat, prone bench pull, and shoulder press found that velocities associated with stopping a set before failure were highly reliable (coefficient of variation: 4.4-8.0%) at 2,4,6,8 RIR when looking at 65, 75, and 85% 1RM in each exercise (Morán-Navarro, 2019).

VBT may be used as a form of instantaneous feedback, by providing recorded velocities in real time with the use of a linear position transducer. Feedback has previously been shown to help improve acute performance. Use of VBT for feedback has led to greater improvements in training and greater consistency in training when compared to those not using VBT for feedback (Randell, 2011.).

A six-week training study was conducted using VBT for the bench press investigating the possibility of using velocity to measure different loading intensities. Fifty-six participants completed the study, and despite increasing their 1RM bench press by an average of 9.3% across the population, velocities remained consistent at a given %1RM (González-Badillo, 2010).

Monitoring velocity may potentially aid in estimating and potentially limiting metabolic stress such as buildup with ammonia, which has been shown to increase recovery times (Sanchez-Medina, 2011). Implementation of programs utilizing velocity loss are a growing modality of periodization, where velocities are prescribed and a percent velocity decrement is used to determine completion of a set (Banyard, 2019.). Improvements in hypertrophy were found in both programs using 20% velocity loss and 40% velocity loss thresholds, with greater improvements found in the 40% group (Pareja-Blanco, 2017).

Cluster Sets

Cluster sets have been utilized as a method to increase mechanical overload by increasing total repetition volume in a set under heavier loading conditions than a traditional set would allow (Haff, 2008). Maintenance of acute mechanical performance has been demonstrated previously through comparison of cluster sets of two repetitions and four repetitions when compared to traditional sets (Nicholson, 2016.).

Intra-set rest has been shown to help maintain acute mechanical performance. When looking at high volume back squats maintenance of mean recorded velocities, and power output were conserved in both two-repetition and four repetition cluster sets at 60% 1RM when compared to completing twelve repetitions in a traditional set. The study also showed that the cluster sets of two repetitions demonstrated greater maintenance of these variable, implying that increasing the frequency of intra-set rest periods also helped to maintain performance (Tufano, 2016). Intra-set rest periods of varied lengths have also been studied, with periods as short as six seconds demonstrating decreases in power loss across varied loads with rest periods as short as six seconds (Garcia-Ramos, 2016). Intra-set rest intervals may be manipulated depended on the goal outcome of the training session., but it is important to note that the longer rest intervals may be less practical for strength coaches due to constraints in time with athletes in the weight room. A study observing changes in power output in the power clean clusters while manipulating intra-set rest periods demonstrated that similar maintenance of power output was displayed with twenty and forty second rest intervals and therefore shorter rest intervals may be more practical (Hardee, 2012).

CHAPTER 3

METHODOLOGY

Demographics

Fourteen recreationally active males (age: 21.42±0.90 years; height: 1.75±0.06 m; body mass: 84.29±7.91 kg) participated in the study. All participants exercised three or more times per week for greater than one year. Participants were not required to have experience with cluster sets.

Equipment

- Olympic 20kg barbell
- Kilogram plates (0.5-25 kg)
- Squat stand
- Linear position transducer (GymAware, Kinetic, AU)

Study Design

Prior to testing, all fourteen subjects signed an informed consent form. Height and body mass data was gathered prior to testing. The initial testing day consisted of a 1RM back squat test. All participants completed a standardized ten-minute dynamic warmup prior to each session. After the warm-up participants were tested in the free-weight back squat using the NSCA 1RM protocol (Haff & Triplett, 2015). Upon completion of 1RM testing, a minimum of 72 hours rest period was given to allow for recovery before beginning the experimental sessions. The protocol included two separate experimental trials. Participants were randomized into two groups following 1RM sessions. Each testing sessions consisted of completing one set of ten repetitions at 67% 1RM, one set of

six repetitions at 80% 1RM, and one set of four repetitions at 85% 1RM. All traditional sets were completed on one day while cluster sets were completed on the other. One group completed traditional sets with all of the loads on the first day while the other group completed their sets with the cluster sets first. Traditional sets consisted of all repetitions being completed in sequence followed by a five-minute rest period between sets, beginning when the participant placed the barbell back into the rack. Cluster sets were completed with thirty second intra-set rest periods following every two reps while matching the same total volume as the traditional sets for each condition. Thirty second timers were started when the participant placed the barbell back into the rack and a countdown was given to ensure the participant continued the set after the thirty second rest periods. Five-minute rest periods were included between each set. All participants were instructed to squat to parallel, and to move each rep as fast as they could.

Fatigue was monitored using a questionnaire to assess hours of sleep, quality of sleep, muscle strain, and stress levels prior to each session (Gastin, 2013.). During each trial mean concentric velocities were recorded with a linear position transducer (GymAware, Kinetic, AU) to measure mean concentric velocities of each repetition.

Participants were not informed of their repetition velocities during testing.

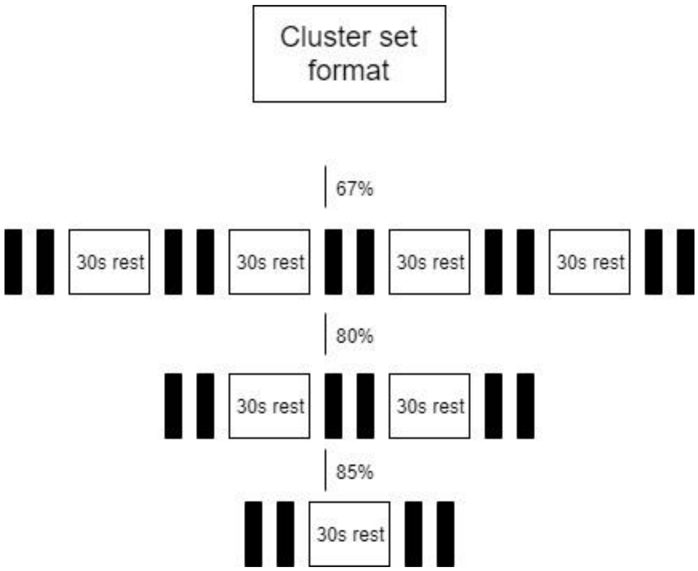

Figure 1. Cluster Set Format

Figure 1 displays the format of sets during the cluster set day. Each cluster of two repetitions will be proceeded by a thirty second intra-set rest period until total repetitions matches with the traditional sets.

Statistical analysis

Statistical analysis was completed using the statistics package for the social sciences (SPSS 25.0). Correlations were determined with an alpha of $p \leq 0.05$. The fastest repetition from each loading condition was used for analysis. Two-way ANOVAs were used to determine differences between mean velocities in the cluster set and traditional set conditions. Two repetition averages were used for each loading condition to compare each cluster with pairs of repetitions. Paired t-tests were used to assess differences in questionnaire results by testing day.

CHAPTER 4

RESULTS

Table 1. Questionnaire Results

Questionnaire Results

	Traditional Day	Cluster Day
Hours of Sleep	6.54	6.75
Sleep Quality	2.21	1.71
Fatigue	2.57	2.43
Muscle Strain	1.93	2.21
Stress	3.36	3.28

This table displays mean results from the wellness questionnaire. Sleep quality, muscle strain, and stress were all measured on a 1-5 scale with 1 being the highest score and 5 being the lowest score. No significant differences were observed in questionnaire scores between testing days ($p>0.05$)

VBT Correlational Data

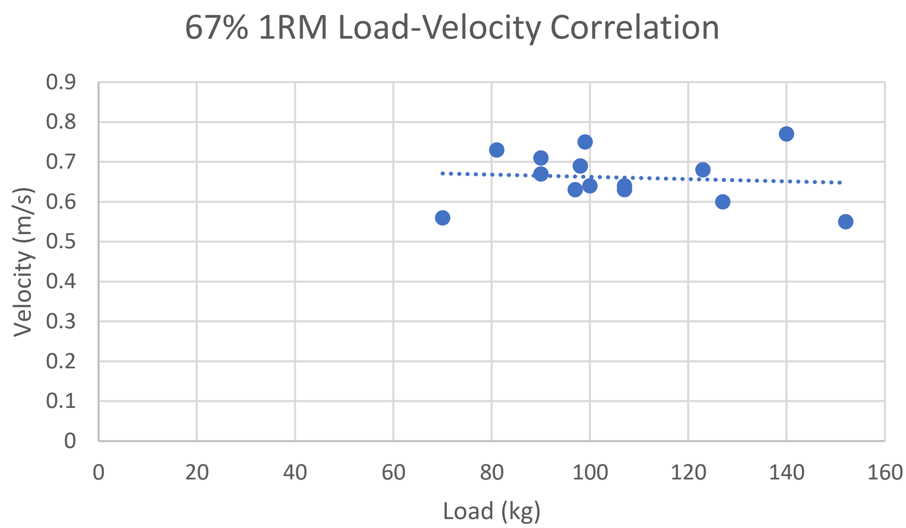

Figure 2. 67% 1RM Load-Velocity Correlation

A trivial correlation was displayed between loads and velocities in the 67% condition (r=-0.096). Outliers on both ends deviated from the trendline shown in the figure.

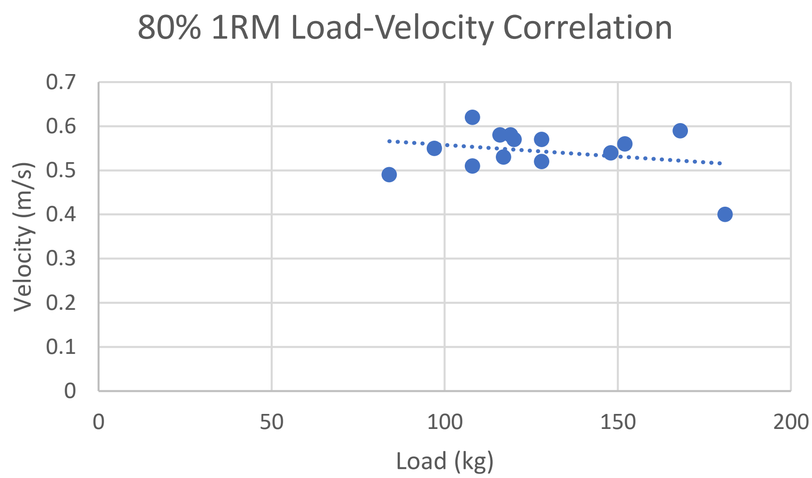

Figure 3. 80% 1RM Load-Velocity Correlation

A weak negative correlation was displayed between loads and velocities in the 80% 1RM condition (r=-0.242).

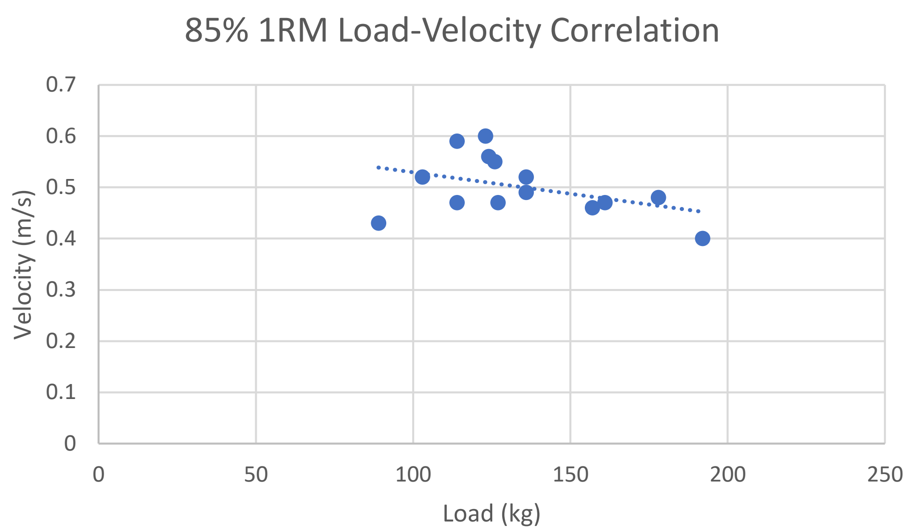

Figure 4. 85% 1RM Load Velocity Correlation

A moderate negative correlation was found between loads and velocities in the 85% 1RM condition (r=-0.41).

Cluster Set Data

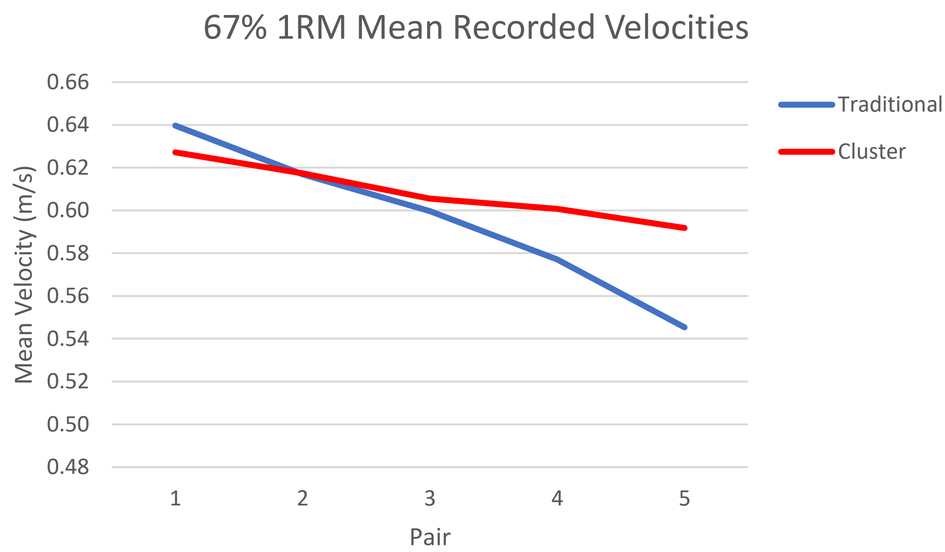

Figure 5. 67% 1RM Mean Recorded Velocities.

Figure 5 displays two repetition averages for mean concentric velocities in the 67% 1RM condition for traditional and cluster sets. A significant difference was found between the recorded velocities in the two sets ($p<0.05$).

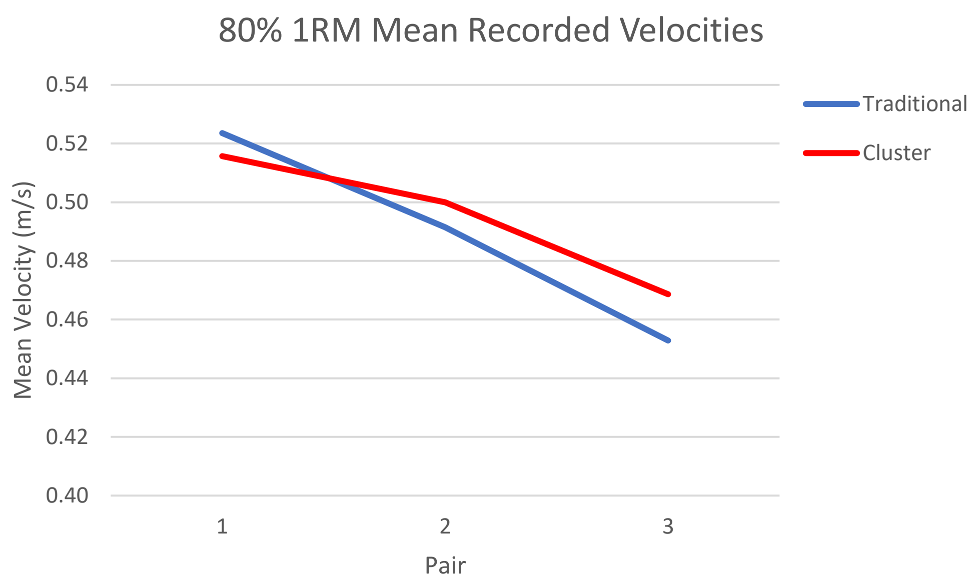

Figure 6. 80% 1RM Mean Recorded Velocities.

Figure 6 shows two repetition averages for mean concentric velocities in the 80% 1RM condition for traditional and cluster sets. No significant difference was found between the two groups (p>0.05). However, pairs two and three did display an increasing mean difference in the cluster condition when compared to the traditional sets.

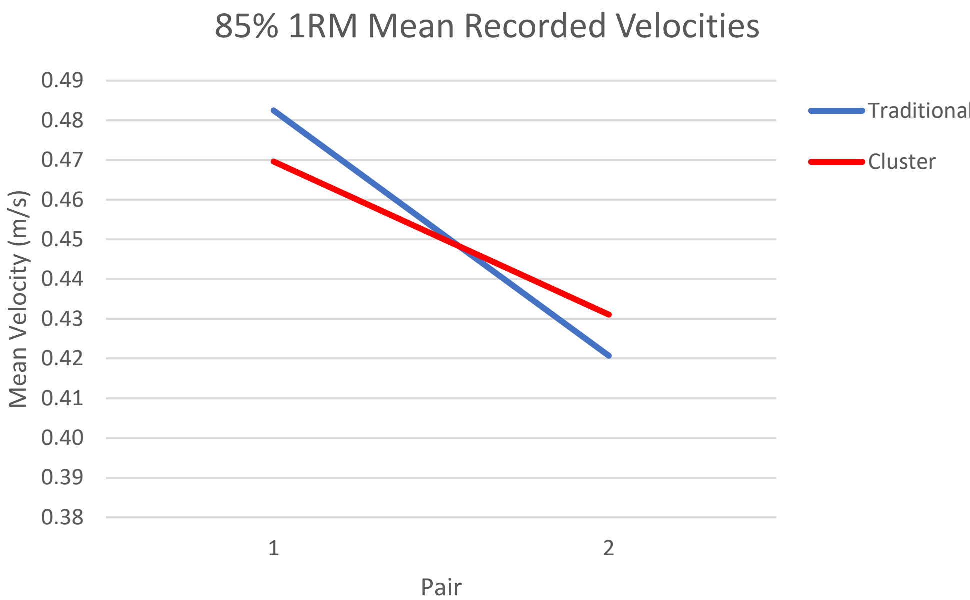

Figure 7. 85% 1RM Mean Recorded Velocities.

Figure 7 shows two repetition averages for mean concentric velocities in the 85% 1RM condition for traditional and cluster sets. There was no significant difference between the two set types ($p>0.05$).

Table 2. Means and Mean Differences

Means and Mean Differences			
	Cluster Set (m/s)	Traditional Set (m/s)	Mean Differences (m/s)
67% Pair 1	0.63	.64	-0.01
67% Pair 2	0.62	0.62	0.00
67% Pair 3	0.61	0.60	0.01
67% Pair 4	0.60	0.58	0.02
67% Pair 5	0.59	0.54	0.05
80% Pair 1	0.52	0.53	-0.01
80% Pair 2	0.50	0.49	0.01
80% Pair 3	0.47	0.45	0.02
85% Pair 1	0.47	0.48	-0.01
85% Pair 2	0.43	0.42	0.01

Table 2 displays means and mean differences for each pair of repetitions under all loading conditions. While significant differences were only observed between set types in the 67% condition, Similar mean differences were shown across %1RM conditions in pairs 1-3 at 80% 1RM as well as pairs 1-2 at 85% 1RM.

CHAPTER 5

DISCUSSION

The questionnaire results displayed no significant differences between testing sessions. However, participants showed high levels of stress on both testing days, potentially affecting the movement velocity of each repetition. Using the questionnaire for inclusion criteria may have been a way to mitigate any issues with fatigue by excluding participants when they answered with a four or five on any question.

No significant correlations were found under any of the three loading conditions (67%, 80%, 85% 1RM). This goes against previously suggested evidence and the ability to generalize velocities into training zones. While the correlations ranged from trivial to moderate across the measured loads, there were large groupings of values that fell around the trendline with a few outliers deviating from the trend. With a greater subject pool, the outliers would have a lesser affect, potentially leading to a stronger correlation than the ones demonstrated in this study.

The lack of correlations between load and velocity across participants implies that individualization may be necessary when determining velocities for VBT. This has also been shown to be true with load-velocity profiling as different muscle and training characteristics may have effects on movement velocity from one individual to another. Individualized load-velocity profiles (LVPs) have previously been shown to have high reliability with the free-weight back squat (Banyard, 2018). Individualized LVPs may allow for more accurate velocity prescriptions for VBT instead of using generalized ranges which have been designated in previous studies. Using LVPs will allow for appropriate development and monitoring of each individual exercise as well rather than relying on general prescriptions across multiple exercises. Using a combination of methods may also be ideal to further gain insight into an individual's performance in an exercise such as combining VBT with set RPEs, RIRs, or session RPEs to help monitor fatigue and auto-regulate as intended with a VBT program. Tracking velocities over a prolonged period could be considered as tool for monitoring fatigue rather than solely for use with prescription of loading.

Maintenance of velocity was not shown as previous research has concluded when comparing traditional and cluster sets. However, this may partially be due to the inexperience of the participants with cluster sets as some research has stated that cluster sets show benefits with chronic training when compared to traditional sets (Nicholson, 2016). Additionally, when looking at table 2, mean differences trend similarly across all conditions, which eventually led to a significant difference in the 67% condition due to an increased number of pairs. With increased repetition volume at greater loads a similar difference may have been displayed when comparing the traditional and cluster sets. Looking at maintenance of power output as well as force data may help to reveal more information about cluster sets and their usage. Recently, rest-redistribution protocols have been shown to maintain peak force output in an even greater manner than cluster sets

(Tufano, 2017). This perhaps calls to the notion that cluster sets should not serve as a replacement for traditional sets but may be used to train a specific capacity when compared to other methods of set structures such as traditional sets or utilization of rest redistribution.

Future Research

In the future, it may be worth controlling repetitions through a true 2 RIR rather than estimating RIR by using estimated repetition maximums at a given %1RM. By reaching a true 2 RIR it may be possible to see if the trends in the 80% and 85% cluster sets continued to match those in the 67% set. Additionally, completing sets to 2 RIR in both the cluster and traditional sets may potentially yield greater total repetition and load volume through clusters if the acute intra-set recovery periods allow for greater total repetitions in each set when compared to the traditional sets. Matching total intra-set rest time across conditions may be worth investigating in the future, as the additional rest time at the 67% 1RM cluster sets (120s) compared to the intra-set rest at 85% 1RM (60s) may have an impact on the results demonstrated in this study. Further investigation of cluster sets may include undulating cluster sets, in which loads can be varied within a cluster set to further induce mechanical overload and potentiation within a single set. Examining other mechanical variables including power output and force output may provide further insight on the benefits of cluster sets. Looking at joint moments and muscle activation may provide more information regarding the mechanism through which mechanical variables are maintained in cluster sets.

Practical Application

VBT is gaining popularity with more widespread availability of commercial linear position transducers. While the present study did not display strong correlations between loads and velocities, using velocity to monitor daily changes in training may still be a useful tool in assessing an individual's fatigue. Estimating 1RMs with VBT prior to training sessions may be an effective way to evaluate an individual's ability to perform which varies with day to day fluctuations (Jovanovic, 2014). Developing individual load-velocity profiles for specific exercises will allow for appropriate prescription of velocities in training. Loads can be prescribed in terms of velocity to match the more traditional %1RM load prescription or velocity loss thresholds may be used to further control fatigue by terminating a set when velocity decreases by a set percentage (Pareja-Blanco, 2017).

Cluster set implementation may be used to provide further mechanical overload in a set when compared to traditional sets. By introducing acute recovery periods, greater overload may be achieved through increased loading or total repetition volume. Previous studies have shown maintenance of power output, making cluster sets useful when power is the capacity that is being focused on (Tufano, 2016). Furthermore, while cluster sets have been shown to maintain power output, they may still be utilized for multiple phases of training. When focusing on hypertrophy or conditioning, the use of cluster sets will allow for greater total volume through added repetitions with shorter intra-set rest periods when compared to cluster sets with heavier loads.

CHAPTER 6

CONCLUSION

No correlations were found between loads and velocities for the given group implying that individualization may be key when prescribing periodized programs which utilize VBT. Significant differences were only measured in the 67% condition when comparing recorded velocities between traditional and cluster sets. However, additional repetitions under heavier loads may lead to greater maintenance in velocity as displayed in previous studies

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APPENDIX A

EAST STROUDSBURG UNIVERSITY

East Stroudsburg University Institutional Review Board
Human Research Review
Protocol # **ESU-IRB-062-1819**

Date: **April 18, 2019**
To: **Dylan Zangakis and Gavin Moir**
From: **Shala E. Davis, Ph.D., IRB Chair**
Proposal Title: **"Velocity Based Training and Cluster Set Application for the Back Squat"**

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:

APPENDIX B

Informed consent for scientific study

***Title of investigation**: Velocity Based Training and Cluster Set Application for the Back Squat*

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***Principle investigator**:* Dylan Zangakis

Overview of study

Velocity based training (VBT) has been proposed as an auto-regulatory approach to training. Typically, training loads are determined using percentages of a one repetition maximum (%1RM). However, this may create issues on days where an athlete is either fatigued or dealing with external stress factors which limit their ability to perform. The purpose of the study is to determine relationship between prescribed velocities for a given %1RM when utilizing VBT for the back squat. In addition, the study aims to use kinematic data to assess maintenance of velocity and power output in cluster sets.

Testing sessions

There will be three testing sessions during the study. The testing sessions will be performed in the Biomechanics Laboratory of East Stroudsburg University. During the testing session you will be asked to perform repetitions of the squat under various loads (67%, 80%, 85%) based on one repetition maximum testing. Prior to all testing sessions 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

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNITURE INDICATES THAT YOU HAVE READ THE INFORMATION PROVIDED AND YOU HAVE DECIDED TO PARTICIPATE IN THE STUDY.

I have read and understood the above explanation of the purpose and procedures for this study and agree to participate. I also understand that I am free to withdraw my consent at any time.

____

Print name

____________________ ____________________ ______________

Signature Witness signature Date

APPENDIX C

Questionnaire

Testing Day (Cluster/Traditional):______________________

How many hours of sleep did you get last night?

How would you rate your quality of sleep (1 being the best-5 being the worst)?

1 2 3 4 5

What is your current level of fatigue?

1 2 3 4 5

What is your current level of muscle strain?

1 2 3 4 5

How would you rate your current stress?

1 2 3 4 5