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Effects of Three Different Loading Models on Strength and Body Composition in Resistance Trained Persons

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Abstract

Background: Periodization of the annual training plan is a commonly utilized tool within the strength and conditioning community. Within the periodized plan, load is a key variable that is often manipulated to optimize strength development. At the present moment, a common model for load prescription involves the use of a percentage-based training (PBT) plan. However, inherent problems within a PBT loading model may reduce the accuracy of the training stimulus due to various reasons including atypical one repetition maximum (1RM) performance, strength improvements, or an acute decrease in an individual's ability to perform. Thus, autoregulatory loading models may be a more suitable modality for load prescription due to increased individualization of training loads. ***Purpose:*** To explore the effects of three different loading models on strength and body composition in resistance trained persons. ***Methods:*** An experimental, randomized cross-over design was used consisting of 23 resistance-trained persons. Participants were randomly divided into one of three groups: PBT (8), velocity-based training (VBT = 7), rating of perceived exertion-based training (RPE = 8). An initial assessment measured participants body weight, body composition via skinfold calipers, and 1RM for the barbell back squat, bench press, and deadlift. The training intervention consisted of training 3x/week on non-consecutive days. Following an eight week periodized training intervention, participants returned for a post-test. ***Results:*** Significant within group time interactions were observed ($P < .0001$) for the back squat, bench press, deadlift, and total. No between group significant differences were observed for the back squat ($P = .727$), bench press ($P = .751$), deadlift ($P = .437$), and total ($P = .599$). ***Conclusion:*** Various loading models may be used to increase strength in resistance trained persons. Despite these findings, autoregulatory loading models may still have merit for individualizing training load, particularly in experienced lifters.

Keywords: Velocity-based training, percentage-based training, RPE, periodization, autoregulation, loading models

Chapter I: Introduction

Background of the Problem

Over 79 million adults partook in some form of resistance training in the United States in 2020 (Elgaddal et al., 2022). Motivations for resistance training are multifaceted and interdependent but may include social approval dependence, appearance improvement, training pleasure, and physical performance improvements (Awruk & Janowski, 2016). Resistance training is particularly effective for improving strength (physical performance) and body composition (appearance improvement) (Buford et al. 2007). To optimize these outcomes, practitioners are continuously looking to facilitate the adaptive process through training stimulus. Beyond this, load is also of particular importance to mitigate chance of injury (Winwood, 2013). In simpler terms, training too "easy" may result in less than optimal adaptations. Training too "hard" may result in injury or overtraining.

One common tool to help optimize outcomes is the use of a periodized training plan. Periodization is defined as the planned modulation of training variables such as reps, sets, load, rest, and more, to maximize performance (Mann et al., 2010). Sports scientists, coaches, and athletes use the principle of periodization developed by Leo Matvyev in the 1970's to illicit strength and hypertrophic adaptations. Swinton et al. found that 96.4% of high-level powerlifters (defined as an average Wilks score of 450 ± 34.7) employed some form of periodization in their training (Swinton, et al., 2009). Additionally, the use of periodized training plans has been found to produce superior strength adaptations when compared to non-periodized training plans (Buford et al., 2007; Rhea & Alderman, 2004; Williams et al., 2017). One common element of most strength training periodized plans is the use of percentage-based training (PBT) loading model to prescribe and vary training loads (Dorrell et al., 2020; Orange et al., 2020). Within this model, a one repetition maximum (1RM) must initially be determined through testing. Once a 1RM is determined, training is typically based on a percentage of the 1RM. However, a 1RM may not be accurate due to atypical performance when testing the 1RM, strength improvements, or an acute decrease in an individual's ability to perform. Thus, a traditional PBT loading model may provide an inappropriate stimulus. Lastly, untrained individuals appear to respond favorably to most novel stimuli (Kraemer & Ratamess 2004). Therefore, a more individualized approach to load prescription stands to benefit experienced lifters to the greatest extent (Helms et al., 2017).

Individualizing a training intervention may be important because of the myriad of adaptive responses within an individual. These differing responses lead to the well-recognized challenge of both intra-individual adaptive variability (INTRAAV) and inter-individual adaptive variability (IAV). While research largely supports exercise as a means to improve various aesthetic and performance markers such as body composition and strength, training stimuli do not produce a uniform response (Ahtiainen et al., 2016; Hubal et al., 2005; Montero & Lundby, 2017). For example, Hubal et al, assessed the effects of resistance training IAV in 585 participants on body composition and strength with a pre-planned repetition maximum (RM) program (2005). Despite significant improvements in both outcomes, the range of outcomes was relatively large with eight and twenty-fold differences between the lowest and highest responders when looking at hypertrophy and strength respectively. These observations leads us to recognize that the use of the aforementioned training model incorporating pre-planned PBT may be inappropriate for optimal progression as some individuals may respond differently to a specific stimulus based on a variety of factors including genotype (Bouchard & Rankinen, 1999), gender (Hubal et al., 2005) training history (Mann et al., 2014), concurrent activity (Ahtiainen et al., 2016), nutritional intake (Ahtiainen et al., 2016), sleep and stress (Mann et al., 2014), and training workloads (Mann et al., 2014).

More recently the use of autoregulatory models has become a popular training modality to address both INTRAAV and IAV. Auto-regulation (AR) can be defined as altering daily and weekly training parameters based on the individual's rate of adaptation and/or daily readiness (Mann et al., 2010). These parameters include but are not limited to training modality, intensity, frequency, and volume. AR can be accomplished through subjective or objective metrics. Common subjective autoregulatory tools for resistance training have been a modified rating of perceived exertion (RPE) scale or repetitions in reserve (RIR) scale. An emerging form of objective autoregulation (AR) is measuring barbell velocity using a linear position transducer (LPT) (Zhang et al., 2021). Here, the LPT is attached to a barbell to give instantaneous feedback about the velocity of an exercise/movement. The velocity at which the barbell moves has been shown to be a reliable surrogate measure of training intensity (Stock et al., 2011). Proven moderately to highly reliable, velocity-based training (VBT) may then be used in place of PBT to prescribe training loads. For this to take place, an individualized velocity profile must first be developed. Once developed, training load can be autoregulated based on velocity targets or zones. Therefore, in place of a fixed training load, the load fluctuates based on the target velocity zone for the day. At the present moment, research on the efficacy of AR loading methods remains unclear.

Purpose of the Study

The purpose of this study was to explore the three different loading models on strength and body composition in resistance trained persons.

Research Questions and Hypothesis Testing

RQ1. Is there a significant difference between VBT, PBT, and RPE loading models, pre-post test, for strength improvements.

> $H1_0$ There is no significant difference between VBT, PBT, & RPE for strength improvements.

> $H1_a$ VBT is a significantly more effective loading model than PBT and RPE for strength improvements.

RQ2. Is there a significant difference between VBT, PBT, and RPE loading models, pre-post test, for body composition improvements.

> $H2_0$ There is no significant difference between VBT, PBT, & RPE for body composition changes.

> $H2_a$ VBT is a significantly more effective loading model than PBT & RPE for body composition changes.

RQ3. Is there a significant difference between VBT, PBT, & RPE loading model for reducing perceived stress.

> $H5_0$ There is no significant difference between VBT, PBT, & RPE for total perceived stress.

$H5_a$ VBT is a significantly more effective loading model than PBT & RPE for reducing perceived stress.

RQ4. Is there a significant difference between VBT, PBT, & RPE loading model to improve perceived recovery status.

$H7_0$ There is no significant difference between VBT, PBT, & RPE for improving perceived recovery status.

$H7_a$ VBT is a significantly more effective loading model than PBT & RPE for improving perceived recovery status.

RQ5. Which loading model demonstrates the least amount of pre-post adaptation variability for maximum strength?

Chapter II: Review of Literature

Introduction

The focus of this section is to provide an appropriate foundation for the reader to better understand the justification for this study. The author starts with a look at theoretical and conceptual underpinnings to help serve as a framework to understand how research has evolved within the resistance training community over the last century. This is then connected to a brief overview of periodization. Finally, various load prescription models are explored and connected to our current gaps in the research.

Theory

Resistance training and adaptation research has evolved considerably since its early established roots from researchers such as Hans Seyle and Thomas Delorme in the 1930's and 1940's. This evolution continues to push the field to new forefronts and create new paradigms heavily followed by practitioners today. While mostly positive changes have occurred, it is in the author's opinion, current resistance training paradigms at times display a reductionist approach to optimizing performance. This is readily apparent in various works ranging from specific sets and repetitions (Berger, 1965; O'Shea, 1966), to periodization styles (Fleck, 1999; Issurin, 2010; Rhea & Alderman, 2004), to autoregulatory loading models (Helms, 2017; Mann et al., 2010; McNamara & Stearne, 2010; Orange et al., 2019). While these are critical to the development of the sports sciences, a deeper look at the complex interaction of systems is needed. While the aforementioned variables are of immense importance, adaptiveness of an organism can also be attributed to other factors within the system and thus warrants further consideration.

General Systems Theory

Aristotle's axiom stated, "the whole is greater than the sum of its parts". Research within the resistance training community (and sports science community as whole) is often dwindled down to perform "X" number of sets and "Y" amount of reps under "Z" amount of load, while controlling for confounding variables, should produce "alpha" result. Ludwig Von Bertalanffy wrote on the conceptual paradigm of modern science which has come to "resolve and reduce complex phenomena into its elementary parts and processes" (1972, p. 409). In this sense, the complex phenomena can be considered the adaptive process, while the elementary parts can be considered sets, repetitions, training load, etc. What modern science sometimes fails to address is the inter-activeness between the elementary parts, both known and unknown. General systems theory (GST) first conceptualized by Bertalanffy approaches the sciences from a diametrically opposed position. He looked to understand the "wholeness" of specific phenomena. Several key principles of GST and dynamic systems theory (DST) shall be discussed: stability, non-linear effects, circular causality, and multifinality and equifinality.

Stability attempts to explain the responsiveness of any system to a perturbation and is particularly relevant to the adaptive process. If a system is met with any perturbation, and upon adjustment, returns to its original state, it is said to desire a state of stability. As it pertains to resistance training, the system can be the human organism while the types of perturbations can be limitless, including relative intensity, training modality, and less known perturbations such as heat, cold and, disease, etc.

The principle of non-linear effects is an aim to understand the relationship between variables that may disrupt stability. In a linear effects example, a change in variable "x" would produce a proportional change in "y" variable. However, non-linear effects in DST states a change in variable x can lead to either a proportional change in "y" or a disproportionate change in “y”. Pol et al. use the activation firing threshold of motor units as an example (2019). Instead of proportionate changes occurring, once a certain threshold is achieved, a disproportionate change occurs, muscular innervation. More relevant may be a change in total training volume. Some research supports a somewhat linear or graded dose-response relationship for training volume and strength (Ralston et al., 2017). However, this is not a linear response, and further, too large a training volume within a single session may be sub optimal (Ribeiro et al., 2015).

Circular causality explains changes (or adaptations) can occur within a system from a top down or bottoms up approach. Human DNA and genetics provide an appropriate fit for this theorical lens. The prevailing wisdom would suggest we are given a specific set of genes which determine many human characteristics (Balague et al., 2017). However, we have recently learned that epigenetics is contextually dependent. Humans can alter gene function through various epigenetic altering processes such as exercise history (Bagley et al., 2020). Understanding exercise history is a critical piece of information when prescribing load.

The last set of principles of relevance are multifinality and equifinality which dictate that various paths can lead to a singular outcome and a single path can lead to various outcomes. Again, using the human organism as the system and an increase in maximum strength the outcome, GST would state there are many paths to achieve the target outcome. Within the human organism, many different paths or loading models can achieve an increase in strength. While not initially intended as a framework for the adaptive process, it stands to reason that GST & DST may help practitioners’ global perspective on training.

General Adaptation Syndrome

While Bertalanffy was working on GST, Hans Seyle was developing his own work on stress theory. Seyle has been termed the father of modern stress research. Strength training and periodization theory has been heavily rooted in Hans Seyle's work on stress (Chu & Barnes, 2003; Kiely, 2017). Seyle's initial concept came in 1925 while in medical school. Here, students were exposed to several patients with differing diseases. Seyle noticed each patient, despite having differing diseases, showed signs of similar symptoms: coated tongue, joint pain, and intestinal disturbances. Throughout the next decade, Seyle worked towards understanding these "nonspecific" symptoms. Finally, in 1936 he produced his first work "A syndrome produced by diverse nocuous agents." The term nocuous agents would later be re-termed into stress. Stress produced a similar reaction which took place in three stages:

1. Alarm Reaction
2. Stage of Resistance/Adaptation
3. Stage of Exhaustion

Seyle went on to outline other key aspects of his work. First is the delineation between the term stress and state of stress: a state of stress is the non-specific response of the body to any demand or stressor and a stressor is the causative agent. Additionally, Seyle also stated the total response of the body to an agent is proportionately linked to the intensity of the aggression. This is a critical element cited by many periodization theorists.

Conceptual Model Example

Perhaps the most fitting application of GST and DST is George Engel's bio-psycho-social model of health (1977). Engel called for a change to the current paradigm amongst medical practitioners at the time, the biomedical model. The model was said to explain all deviations from homeostasis within a biological framework. All deviations or diseases were said to be completely independent of psychological and/or social reasons. Similar to Bertalanffy, Engel argued that the biomedical model was overly reductionist and biology could not account for every deviation from homeostasis. On the other hand, the biopsychosocial model, Engel argued, was more comprehensive. He stated:

> A medical model must also take into account the patient, the social context in which he lives, and the complementary system devised by society to deal with the disruptive effects of illness, that is the physician's role and the health care system. (Engel, 1977, p. 132)

Collectively, both Seyle's and Engel's works fit within a GST and DST framework. The stressor or causative agent can be considered a physiological or environmentally imposed stress such as resistance training or heat. These stressors disrupt the organism's stability. However, a stressor may also be a psychologically demanding life event like death of a family member. Elements such as grief, as proposed by Engel, can be connected to Seyle's model which produce very real physiological changes within the body. How an individual adapts to grief can be viewed from a circular causality view. Grief can be viewed as a top-down effect as the brain's interpretation of grief will affect the system. Additionally, there is the possibility of a previous exposure to grief affecting the epigenetics of our DNA as well (Seiler et al., 2020). Similarly, existing research shows how past exposures to resistance training adjust DNA expression, so we must acknowledge the possibility of psychological stress affecting epigenetics (Bagley et al., 2020). Taken together, the adaptive process should be seen as a complex phenomenon which may be difficult to predict.

From Theory to Application

The exploration into a theoretical framework helps provide a strong foundation into subsequent training approaches. While resistance training stressors are not perfect parallels to health stressors like disease, Seyle and Engel both suggest that physiological changes may take place through any stressor. Recognizing that any stressor can affect health outcomes, one may postulate that any stressor may affect performance. Improving our understanding of varying stressors and their complex interactions during the adaptive process, sports scientists can improve training interventions.

Training Interventions

Periodization History

The manipulation of training stressors or variables is important for a continuous adaptive process. Thus, it is generally agreed upon that periodized resistance training programs show superior results when compared to non-periodized programming for strength development (Buford, 2007; Fleck, 1999, Rhea & Alderman, 2004; Williams et al., 2017). Therefore, a clear understanding of periodization is a prerequisite for AR research. The earliest forms of periodization can be traced back to the second century AD from ancient philosophers Galen and Philostratus (Bompa & Buzzichelli, 2018; Issurin, 2010). In his work “Preservation of Health”, Galen approached topics such as strength before speed. Meanwhile, the Greek scientist Philostratus described an Olympic build up that included 10 months of pre-training, followed by 1 month of purposeful training to prepare for the games. Philostratus also suggested the specification of workloads such as small, medium, and large. These pre-modern concepts remain a cornerstone of training paradigms today.

Fast forward to the 20th century, the father of modern periodization is widely considered to be Leo Matveyev. Matveyev released his famous work "Fundamentals of Sports Training" (1981). It is important to recognize that Matveyev's text is not a structured program specifically tailored to any one sport, instead, Matveyev attempts to provide a conceptual framework which can be applied across all sports as a training model. Additionally, instead of prescribing exact training loads, a framework of training is laid out. For example, periodization encompasses the classification of training cycles as either general preparatory or specific preparatory. Throughout the text, readers are continuously reminded that achieving peak human performance is a complex dynamic, which addresses the physical, social, and psychological elements of training. These reminders underscore the complex nature of training programming and fall in line with theoretical frameworks previously outlined.

Matveyev goes on to describe training load as an additional functional activity, beyond that of basic human function. Training load can be quantified both externally and internally. External training load represents the modern understanding of load expressed through quantification of training variables such as duration, number of reps, speed, tempo, and volume of weight being lifted. Internal training load represents acute responses to training such as heart rate, ventilation or perceived exertion for example. External training load is most commonly manipulated through intensity and volume alterations. He furthers his argument about the importance of manipulating training load with statements implying that in order to improve performance, there must be an increase in training load. This has important implications as load variation is one of the many cornerstones of the modern periodization model. Load and recovery are based on Russian biochemist Nikolai Yakovlev's principle of supercompensation and closely related to the GAS. Supercompensation states; prior to a specific training session we exist with a given level of fitness. As the training session continues our fitness level will decrease because of accumulated fatigue. Following the training session there is an acute reduction in athletic capability due to fatigue from both neuromuscular inhibition and substrate depletion. In a 24-72-hour period the body will “supercompensate” and restore itself to a given fitness level that is above the original fitness level prior to the training session. If no further training stimulus is induced, an athlete’s fitness will return to baseline over time. By continuously putting an individual through stimulatory training sessions and in turn continuously experiencing the benefits of supercompensation, fitness will continue to rise throughout a training cycle. A key goal of any practitioner is to determine the appropriate stimulatory load.

Strength Training Periodization Models

Since its induction, several forms of periodization have risen to prominence including linear, non-linear (daily/weekly undulating), block, fractal, and conjugate (Harries et al., 2015; Vickers et al., 2010). In 1981, Stone & O’Bryant adapted Matveyev’s work to apply directly to strength training while employing Hans Seyle’s General Adaptation Syndrome (GAS) as a theoretical framework (1981). Based on the GAS model, Stone & O’Bryant pioneered a systematic structure to resistance training for decades to come. Their theoretical model, later coined “linear periodization”, includes 4 phases, hypertrophy, basic strength, strength & power, and peaking/maintenance. An adapted table can be seen in table 1.

Table 1

Linear Periodization

Phase	Hypertrophy	Basic Strength	Strength &	Peak or
Sets	3-5	3-5	3-5	1-3
Reps	8-20	2-6	2-3	1-3
Days/Week	3-4	3-5	4-6	1-5
Times/Day	1-3	1-3	1-2	1
Intensity Cycle	2-3/1	2-4/1	2-3/1	-
Intensity	Low	High	High	Very high or low
Volume	High	Moderate to high	How	Very low

Note. Adapted from "A Theoretical Model of Strength Training" by M. Stone et al., 1982, *NSCA J, 4*(4), p. 36-39. Copyright 1982 by the National Strength and Conditioning Association. Used with permission.

The study looked at three different populations: twenty students within a weight training class at Louisiana State University (LSU), six high level Olympic weightlifters, and thirty-one high school football players. In all three populations, strength was improved to a greater extent using the linear periodization model than the prior 3x6 training model proposed by O'Shea (1966). Despite these findings, in 1988 Charles Poliquin argued that increasing intensity/load in a linear fashion, however, did not provide enough recovery for an athlete (1988). Further, the benefits gained during hypertrophy blocks are attenuated during higher intensity/lower volume blocks. Instead of gradually progressing intensity while decreasing training volume via a wave-like design which was put forth by Matveyev, Poliquin argued that alternating volume and intensity into much shorter blocks (1-2 weeks) would allow more time for "regeneration" and better maintenance of hypertrophy in the later stages of training. An example of Poliquin's model can be found in table 2. In stark contrast to Stone's model, the reader can see both intensity and volume fluctuating during the 12-week training plan outlined. While the nuances of each form of periodization are not relevant to the current study, it is clear that the manipulation of load plays an important role in strength development.

Table 2

Undulating Periodization

Weeks	1-2	3-4	5-6	7-8	8-10	11-12
Reps	10-12	4-6	8-10	3-5	5-7	2-3
Sets	3	5	4	5	4	6
Intensity	70-	82-88%	75-78%	85-90%	80-85%	90-95%
Volume (reps)	30-36	20-30	32-40	15-25	20-28	12-18

Note. Adapted from "Football: Five Steps to Increasing the Effectiveness of Your Strength Training Program" by C. Poliquin, 1988, *Strength & Conditioning Journal, 10*(3), p. 34-39. Copyright 1988 by the National Strength and Conditioning Association. Used with permission.

Load Prescription History

Regardless of individual periodization differences, to optimize development for strength and body composition, load manipulation strategies are of key importance (Kraemer & Ratamess, 2004). At the present time, the popular traditional loading model appears to be the use of a PBT structure (Gonzalez-Bandillo, & Sanchez-Medina, 2010). Within a PBT loading model, athletes first must determine a 1RM. This represents the most amount of weight that an athlete can lift for a specific movement typically found during an assessment. Once a 1RM is achieved, subsequent training is prescribed as a specific percentage of their respective 1RM.

While PBT has been the heavily favored method of load prescription in recent times, it was not the first. Throughout modern resistance training history, two models of load prescription have dominated: 1.) PBT as previously described, and 2.) repetition maximum targets (Thompson et al., 2020). The latter of which was pioneered by Thomas L. Delorme.

In 1945, Delorme aimed to restore power and strength of 12 patients with varying injuries sustained to the knee (1945). At the time, the common goal of rehab would be to develop muscular endurance to an atrophied muscle first, prior to strength. Delorme aimed to reverse this order. Upon an initial visit, patients performed a knee extension exercise working up to the most weight they could lift for 10 repetitions (10RM). Once this was completed, patients would then work up to 1RM on the same exercise. Each session patients worked up to a 10RM in seven sets. Delorme found that post treatment, his new methodology far surpassed that of current practices at the time for rehabilitation. More importantly for the strength and conditioning community, four elements were born out of Delorme's work:

1. 1RM assessment for maximum strength
2. 10RM assessment for strength
3. Progressive Resistance Exercise (or progressive overload)
4. Load prescription model based on objective data.

While the history of load prescription utilizing repetition maximum targets appears to be clear, it is more difficult to ascertain the origins of load prescription based solely on PBT. The earliest periodized plan involving relative load prescription recommendations appear to be related to a recommendation from Berger in 1965 indicating strength should be developed at two thirds of a 1RM (1965). Furthermore, one of the earliest and most influential PBT periodized plans appears to be Poliquin's 1988 paper utilizing a PBT loading model within an undulating periodized program. (1988). These researchers and practitioners laid the groundwork which has dominated modern resistance training philosophies.

Summary

Periodization models have evolved since their modern inception by Matveyev. An underlying theme within periodized models is the manipulation of loading. The two common loading models of the modern era are built upon repetition maximum targets and PBT. Specifically with regards to a PBT loading model, athletes may be in heightened or reduced performance states. This may be due to a multitude of factors including but not limited to training fatigue, dietary habits, sleep, life stress, etc. Listed below, are problems which may arise within any PBT models:

1. A 1RM must be found. Higher relative loads have been associated with increased injury risk. (Strömbäck et al., 2018; Winwood et al., 2014)

2. 1RM assessment is time consuming (Chapman et al., 1998)

3. PBT models may not accurately prescribe load due to inherent variability between exercise selection (Hoeger et al., 1987) and individual/population characteristics (Richens & Cleather, 2014)

4. PBT models may not accurately prescribe load due to a rapidly changing 1RM, especially for those new to strength training (Hakkinen, 1985; Kraemer & Fragala, 2006)

5. The individual adaptive process is highly variable. Predetermined PBT methods do not take into account individual rates of adaptation. (Bouchard & Rankinen, 1998; Hubal et al., 2005)

Inter-Individual Performance Differences

While training studies have borne out ideal training loads, sets and repetitions, most published results, and thus practitioner recommendations, often look at mean outcomes. However, there is a great deal of variability in performance at different relative intensities for both differing exercise movements and target populations. For example, Hoeger et al found that participants could perform 15.2 ± 6.5 repetitions for the leg press at 80% of their 1RM (1987). However, for the bench press they could only perform 9.8 ± 3.6 repetitions. This variability grew wider at a lower relative intensity. At 60% 1RM 33.9 ± 14.2 repetitions were performed on the leg press and only 19.7 ± 4.9 were performed on the bench press. If we assume that training within a given proximity to failure ideal for both strength and muscular hypertrophy (Grgic 2022 et al., 2022; Lasevicius et al., 2022; Pareja-Blanco et al., 2017), it is clear that training at specific relative intensities may not provide an appropriate training stimulus across all exercise movements due to the inherent performance variability, both inter-participant and inter-exercise. Furthermore, blindly applying relative intensities across all exercises is likely to not elicit the same stimulus for each individual. If strength is to be maximized within a specific proximity to failure, PBT may inherently over or under prescribe repetition targets.

This can be illustrated following Poliquin's training percentages and applying Hoeger's findings across different exercises. If in weeks 8-10, individuals are to perform 7 repetitions at 80% of their 1RM, the leg press exercise on average would be 8 repetitions from failure, while the bench press would be 2 repetitions from failure (Poliquin, 1988). This is exacerbated by the fact that the average repetitions performed in the Hoeger study had standard deviations of 6.5 and 3.6 in the leg press and bench press respectively. Therefore, some participants falling 1 standard deviation below the mean (6.2 repetitions) would not even be able to perform a single set of 7 at 80% of a 1RM.

Differences in repetitions to failure are further complicated depending on the target population being assessed (Desgorces et al., 2010). It has been shown that “high endurance” groups were able to perform significantly more repetitions at relative intensities ranging from 20% to 75% 1RM than “high strength” groups (powerlifters and racket ball players). Similarly, researchers found endurance athletes were able to perform 19.8 ± 6.4 repetitions at 80% 1RM, while strength athletes could only perform 11.8 ± 2.7 repetitions (Richens & Cleather, 2014). Once again, such large discrepancies present an inherent problem within PBT models looking to optimally develop strength and muscular hypertrophy.

Inter-Individual Adaptive Variability

Analysis and recommendations based on mean outcomes from research is further complicated when looking at IAV to exercise. While this is understandable and important to determine if a significant difference is present between groups, the mean does not describe the range of individual responses. The range of individual responses often times constitutes a broad spectrum as opposed to what is often displayed in research, a tight mean response. This broad adaptive spectrum is important to understand IAV, both for high-responders (adaptation above the mean) and low-responders (adaptation below the mean). It should be noted that early studies looking at IAV aimed at understanding cardiorespiratory responses instead of resistance training as they have broader ranging health implications. Prud’Homme et al produced the first piece of research exploring adaptive variability in 1984 on 10 myzogotic twins, which saw a 12% improvement in maximal aerobic power after a 20-week intervention. Interestingly, individual improvements ranged from 0-41% (Prud’Homme et al., 1984). This led to the development of the HERITAGE family study where 481 sedentary individuals, from 98 two generation families, partook in a 20-week cycle ergometer training intervention to determine the role of genotype in adaptive responses to regular exercise (Bouchard et al., 1999). In essence, the researchers aimed to explore the role genetics accounted for in the adaptability of participants. They found that the maximum amount of inheritable VO_2max response to training was 47% when adjusting for age and sex. Other findings include a 2.5 times higher variance in response to training between families when compared to within families. The researchers stated, “some individuals exhibit a pattern of high response, whereas others present a pattern of no or minimal response” (Bouchard, 1999, p. 1007). These findings support that IAV may be based on specific genetic phentotypes passed on from family members. But more specifically, this early research identified a wide range of adaptive response to identical training interventions.

In 2005, Hubal et al produced the first resistance training study with a relatively large cohort looking at IAV in muscle size and maximum strength (2005). Five hundred eighty-five healthy young adults ages 18-40 underwent a 12-week unilateral elbow flexor training. Results include an 18.9% ±0.4 increase in muscle size, a 19.5% ± 0.8 increase in isometric strength, and a 54.1% ±. 1.4 increase in 1RM strength. When looking at total number of individual responses for muscle size, 10 subjects gained over 40% in muscle size while 36 subjects gained less than 5%. With regards to maximum strength, improvements ranged from 0 – 250% of 1RM. Thirty-six subjects experienced an over 100% improvement while 12 subjects saw a less than 5% improvement in 1RM. As a coach or athlete, the respective eight-fold and 20-fold difference between high and low responses to this specific intervention cannot be ignored.

Ahtiainen et al found somewhat smaller average improvements of 4.8% ± 6.1% for hypertrophy, as measured by ultrasound, magnetic resonance imaging (MRI), and dual-energy X-ray absorptiometry (DXA) (2016). Strength on average improved 21.1% ± 11.5% on the leg press 1RM. These smaller total improvements may be attributed to the larger age range for the study 22-77 while Hubal et al inclusion criteria restricted their study to 18-40 years. Hypertrophy adaptations ranged from -10.6 to 30.0% after a 20-24-week training intervention in 287 subjects. Strength improvements ranged from -8 to 60%. Once again, these ranges are somewhat smaller than that observed by Hubal et al. But more importantly, a non-uniform response to resistance training was observed in this study. An interesting aspect of the work by Ahtiainen et al was a post-intervention division of subject results into separate quintiles for hypertrophy and strength. Several subjects performed in the lowest quintile in muscle size while performing in the highest quintile for strength. Only 2% of the subjects were in the lowest quintile for both attributes, supporting that hypertrophy and strength adaptations are at least somewhat independent of each other. Similar to Ahtiainen et al, Erskine et al found only one of 53 participants to be classified as a low responder for hypertrophy while being classified as a high responder for strength (2010). Erskine et al also found a range of 18%-113% improvement in 1RM unilateral leg-extension in 53 participants after 9 weeks of training. Lastly, Erskine et al found similar IAV to prior research, seeing 45% coefficient of variability for unilateral leg extension 1RM. This is in line with the 55% CV found by Hubal et al for strength. At the present time, there is convincing evidence with relatively largely powered and controlled studies, suggesting a high degree of IAV given a uniform training stimulus.

To this point the term “low-responders” has purposely been used in place of “non-responders” in this review. It has been demonstrated that training adaptation is highly individualized based on genotype (Bouchard & Rankinen, 1999), gender (Hubal et al., 2005) training history (Mann et al., 2014), concurrent activity (Ahtiainen et al., 2016), nutritional intake (Ahtiainen et al., 2016), sleep and stress (Mann et al., 2014), and training workloads (Mann et al., 2014). In 2010, regarding non-responders Timmons wrote: “no matter what training parameter is studied, “non-responders” are readily observed. For some variables, this equates to 10% of the study population, while for others such as insulin sensitivity, it can exceed 20% of the population” (2011, p. 846).

Non-response, as suggested by Timmons, may be largely mediated by increasing the training stimulus. For example, HERITAGE family study protocol had participants exercising on the low end of training volume per week (150 min) in addition to a lack of high intensity (no exercise above 80% VO2max) (Montero, 2017). An increase in training volume or intensity has been shown to mediate an initial non-response to training. For example, Churchward et al found improvement in at least one variable in all 110 participants when looking at lean body mass, muscle fiber size, leg strength, and physical function (2015). Additionally, the percentage of individuals who did not respond to training after 12 weeks decreased after re-examining them at 24 weeks. Montero et al. completely eliminated non-response in cycling power output by adding two 60-minute cycling sessions to previously determined non-responders current training.

There is little disagreement regarding the heterogenous adaptive response to exercise. But practitioners need to be cautious in our use of the label “non-responders”. Additionally, as Booth and Laye have suggested, responsiveness is not binary (2010). Instead, we should look at adaptations as a graded response based on the myriad of relevant individual variables previously mentioned. Understanding the non-uniform response of individuals to training stimuli is the basis behind the need for AR.

Autoregulation

To better address the non-uniform response to specific training interventions such as PBT loading models, some sports scientists and coaches have gravitated towards autoregulatory forms of coaching. AR is a method of adjusting training variables based on some type of feedback from the athlete (Zourdos et al., 2016). This feedback could come in the form of reps achieved on a set, barbell velocity, rating of exertion, questionnaires, and more. The feedback is assessed on a daily or weekly basis and the training programming for the day may be modified accordingly. Simply put, AR assesses day-to-day readiness and course-corrects programming. Traditional PBT loading models, with pre-programmed workloads, such as Poliquins, cannot account for highly varied contextualized backgrounds of each person. Thus, AR can be used as a tool instead of pre-fixed PBT loading models to perhaps better account for contextualized backgrounds.

Autoregulation History & Evolution

The earliest published forms of AR appear to be from Knight in 1979. Knight adapted the principles of Delorme's Progressive Resistance Exercise technique to fit patients' rehabilitation protocols for post knee surgery/injury called Daily Adjustable Progressive Resistance Exercise or DAPRE (1979). While Delorme outlined the importance of training with increasing resistance, Knight developed a formal method of applying load based on repetitions until volitional failure. Here participants performed a ramp-up protocol with the 1st set being 10 repetitions at 50% of the working weight for the day, and a second set of 6 repetitions at 75% of the working weight. The participant was then to perform as many repetitions as possible on the third set, which served as the feedback for the clinician. Based on how the participant performed during this set, he/she would either add load, keep the same load, or reduce the load on the subsequent set, and session. Knight's use of the DAPRE technique produced an average strength increase of 23.9% in post-injury and post-surgery patients. Knight reported greater and more rapid improvements in strength than prior research using the Delorme method. A key element of the DAPRE method in rehab settings is continuous communication between the patient and therapist, similar to the interaction between an athlete and coach. Lastly, on the non-uniform response of the individual training Knight stated: "technique thus allows for individual differences in strength increases and provides an objective method for increasing resistance in accordance with strength increases. This is necessary for an optimal rate of strength gain" (1990, p. 70).

While Knight pioneered flexible training parameters from a rehabilitation lens, Mel Siff was the first to adapt his model to fit the demands of the strength and conditioning community. He titled his programming method as autoregulating progressive resistance exercise (APRE), found in table 3. Siff added 3RM and 10RM routines which focused on maximum strength or muscular hypertrophy respectively (Verkohoshansky & Siff, 2009). Mann et al. were the first to evaluate Siff's APRE method within the literature. Twenty-three division 1 football players followed either the APRE program and loading model outlined in Supertraining or a pre-determined linear periodized model using PBT (Mann et al., 2010). Over the course of 6 weeks, Mann et al. found significant improvements in 1RM bench press, 1RM back squat, and 225 lb max repetitions bench press in both models. But more importantly he found significant differences favoring the APRE model program when compared to the linear periodized model which utilized a PBT loading model.

Table 3

APRE Loading Model for 6RM

Repetitions	Intensity (Percentage 6RM)
APRE Protocol for 6RM	
10x	50%
6x	75%
Maximum	6RM
Maximum	Adjust weight based on totals repetitions from set 3
Repetitions for Set for Adjustment	
0-2	-5 to -10
3-4	0 to -5
5-7	No Change
8-12	+5 to +10
>12	+10 to + 15

**APRE = Autoregulatory progressive resistance exercise. 6RM = 6 Repetition Maximum

Note. Adapted from "The Effect of Autoregulatory Progressive Resistance Exercise vs Linear Periodization on Strength Improvement in College Athletes" by J. Mann et al., 2010, *Journal of Strength and Conditioning Research*, 24(7), p. 1718-1723. Copyright 2010 by the National Strength and Conditioning Association. Used with permission.

*The number of repetitions performed during the third set is used to determine the adjusted working weight for the fourth set according to the guidelines in column 2

*The number of repetitions performed during the fourth set is used to determine the adjusted working weight for the next day according to the guidelines in column 3.

Subjective Autoregulation

Since Knight's original work, numerous methods have been used to assess daily readiness including but not limited to hormonal markers like salivary testosterone levels, salivary cortisol levels, heart rate variance (HRV), creatine kinase levels, jump height, individualized load progression, perceived recovery scale, RPE exertion, RIR, and barbell velocity (Helms et al., 2020). While some are easily implemented, others require testing and equipment not available to the general public. For the purposes of this paper, the author shall divide autoregulatory metrics into two categories, subjective and objective.

The earliest researched form of subjective AR appears to be the use of the Gunnar Borg RPE 6-20 scale (1970). Within this scale, participants rate their perceived exertion on a scale of 6-20, with 6 being easier than a very, very, light effort and 20 being harder than a very, very, hard effort. The early subjective autoregulatory tool was meant to serve as a compliment to the use of heart rate for gauging and prescribing aerobic exercise efforts. Borg later created a new scale, CR10, with the scale ranging from 0 (no effort at all) to 10 (almost max) (1982). According to Borg, different scales should be used for different purposes, with the CR10 scale having more potential utility for subjective phenomena such as breathing difficulties and aches and pains. As Borg alluded to, more scales were needed depending on the context of measurement. In 2001, Foster et al explored the use of Session RPE to assess global exercise intensity of an entire exercise bout (2001). While initial training intensity assessment methods were more geared towards aerobic training, in 2004 Sweet et al looked to explore the Session RPE and its application to resistance training (2004). The authors found Session RPE to be a valid tool to quantify intensity to "comparable" forms of aerobic. This represents the earliest clear empirical evidence of a valid form of training quantification using RPE for resistance training.

In addition to the prior history discussed, the modern resistance training RPE scale has other roots. Mike Tuscherer's powerlifting training manual Reactive Training Systems combined a 1-10 RPE scale with RIR in an attempt to gauge lifting intensity based on how many more repetitions a person believes they can complete upon cessation of a set (2008). Hackett et al. looked to assessed an RIR scale empirically in seventeen male body builders performing five sets of ten repetitions at 70% of a 1RM. Participants then immediately performed repetitions to failure. Their findings include a strong positive correlation between RIR score and actual repetitions until failure thus creating a valid tool to for assessing intensity and potentially overreaching in athletes (Hackett et al., 2012). Zourdos et al later combined Tuscherer's RPE with Hackett et al's research to explore a RIR-based RPE to autoregulate training loads (2016). Within this modern resistance training intensity scale, instead of values on the 1-10 scale referring to effort, they refer to how many additional reps could have been completed upon the cessation of a set. For example, a 10 within the RIR-based RPE scale means it was a maximal effort and no further repetition could have been completed. A 9 would indicate that 1 more repetition could have been completed. An 8 means 2 more repetitions, so on and so forth. The RIR-based RPE scale was found to have a strong inverse correlation between RPE and average lifting velocity at 60%, 75%, and 90% of 1RM.

Since the inception of RIR-based RPE, (going forward this shall be simply titled RPE for simplicity), several researchers have found utility for RIR and RPE to induce positive strength and/or body composition outcomes (Graham & Cleather, 2019; Helms et al., 2017; Robinson et al., 2023). Subjective measures such as RPE are not without flaws. Most notably, novice lifters may not accurately rate RPE as well as experienced lifters. Zourdos et al found that 100% of experienced squatters accurately assessed a 1RM as RPE of ≥ 9. Meanwhile, 35% of novice lifters inaccurately stated a 1RM was less than 9 (2016). Thus, there may be merit to the exploration of more objective measures of autoregulatory load prescription.

Objective Autoregulation

The following loading models for AR are based on objective data. The aforementioned DAPRE and APRE programs are examples of objectively autoregulated loading models. A more novel approach to loading models has emerged over the last several decades: VBT. Employing the use of a VBT loading model requires an understanding of the LPT. The gold standard for measuring velocity is a three-dimensional motion capture (Perez-Castilla et al., 2019). However, due to their cost and lack of portability, an alternative to measuring velocity and power were required. The LPT has served as a relatively novel tool to assess barbell velocity and inevitably prescribe load. The common use of an LPT involves a base-unit with a string attached to the moving object. The base-unit can then determine the distance traveled and length of time required to travel said distance. These variables can provide velocity and power data on movements such as the back squat, bench press, and deadlift. This can provide instantaneous objective feedback to an athlete or coach.

Linear Position Transducer Validity and Reliability

The validity and reliability of LPT's have been explored by researchers in recent years (Cronin et al., 2004; Garnacho-Castano et al., 2015; Martinez-Cava et al., 2020; Perez-Castilla et al., 2020; Stock et al., 2011). Early research emphasized the validity and reliability of LPT's when compared to force plates (granted this was looking at force instead of barbell velocity)

(Cronin et al., 2004). When looking at average velocity and peak velocity Garnacho-Castano et al. found a high degree of test-retest reliability within a Tendo LPT. They found an ICC of above 0.922 in every category when assessing average velocity, peak velocity, average power, and peak power in the back squat and bench press (Garnacho-Castano et al., 2015). Stock et al. are somewhat in agreement with Cronin et al. and Garnacho-Castano et al. With regards to test-retest reliability of a LPT on the bench press exercise, Stock et al. used a Tendo unit to compare reliability of the bench press exercise in a pre-test, post-test fashion. They found moderate to high reliability at relative intensities ranging from 10% to 70% of participants 1RM. At intensities above 1RM reliability decreased (Stock et al., 2011).

The Tendo unit had been the more researched LPT from 2004-2020 simply because it was one of the first products developed. However, of late, many more commercially available products have entered the market. In 2017, Perez-Castilla et al looked at reliability and validity of seven different velocity tracking devices when compared to the “gold standard”, an optical motion tracking system (2019). Two of the seven devices were LPTs (Chronojump and Speed4Lifts). A near perfect association was found for mean velocity (r range = 0.947 – 0.995) for six of the seven systems. Speed4Lifts (now known as Vitruve, used in the present study) was found to be the most reliable and valid device to measure movement velocity because of its lowest average coefficient of variation across five different relative intensities (45-85%). In a similar study, Martinez-Cava et al compared four different velocity tracking systems to determine intra and inter device agreement. The T-Force system was found to be slightly more reliable than the Speed4Lifts systems with standard of error measurement (SEM) of 0.01 for mean propulsive velocity (MPV) compared to 0.02 (Martinez-Cava et al., 2020). Additionally, Martinez-Cava et al found Speed4Lifts reliability decreased as velocity increased. While this is an important consideration for explosive movements, for the purposes of this study, it is of this author's opinion that powerlifting-style training would not fall under the explosive movement category such as weightlifting. The LPT expected to be used within the current study is an updated model of the Speed4Lift (Speed4Lift) unit.

Velocity-based Training & Load Prescription

Concurrent to the exploration of validity and reliability of LPTs in the early 2000's was the exploration into the relationship between movement velocity and relative training intensities. Badillo and Sanchez-Medina were some of the earliest researchers to put forth the notion of prescribing training loads based on velocity (2010). Mean propulsive velocity (MPV) was found to be highly correlated to an individual's percentage of their 1RM, $R^2 = .98$. Because of this close relationship, the authors suggested coaches or athletes can calculate the % of the 1RM lifted based on the first repetition performed. Additionally, they found that for every increase of 5% in relative load, velocity deceased between .07 and .09 m/s. Therefore, the authors suggested if a subject or athlete were able to increase concentric velocity by .07-.09 m/s at a given load, a coach could infer approximately a 5% increase in strength.

Despite high degrees of validity and reliability completed in the early 2000's, it was not until 2019 that VBT loading model was compared to a traditional PBT loading model within the literature. In a randomized design, Dorrell et al. compared a PBT model to a VBT model on several performance outcomes including strength (2020). A velocity profile was established for each participant within the VBT group as outlined by Sanchez-Medina et al. (2014). Once the profiles were established for each lift (back squat, bench press, strict press, deadlift), velocity training zones and velocity stops were used to determine training load and training volume, respectively. Velocity stops were set at a 20% reduction of the target velocity zone. Of the four major lifts, the VBT group showed a significantly greater improvement in bench press strength than the PBT group (8% vs 4%). While there were no other significant strength differences, the study did reveal another key component regarding volume. Participants were not matched for sets and reps. Because of this the VBT group performed significantly less training volume than the PBT group for the back squat, bench press, and strict overhead press. Therefore, the group was able to show similar improvements in the back squat, deadlift, and strict overhead press, and improve significantly more on the bench press; all on less total training volume. This is in direct contrast to Helms work where the RPE-based RIR autoregulated group performed more total volume than the PBT group. Conversely, Dorrell and colleague's findings on strength are in slight disagreement with Orange et al., who found no pre-post between group differences for 1RM back squat strength in 27 rugby players (2019). Interestingly, despite the similar between group improvements in back squat strength, the VBT group reported lower perceived stress over the course of the 7 weeks. Similarly, Banyard et al. found no significant differences in back squat 1RM in 24 resistance trained males when comparing a PBT loading model to a VBT loading model (2020). Additionally, relative changes favored the PBT group (12% improvement vs 11% improvement). Finally, in 2022, Shattock and Tee compared a VBT loading model using a target velocity zone to an RPE loading model in 20 amateur rugby players looking at strength in the back squat and bench press (2022). While both subjective and objective autoregulatory loading models displayed significant strength improvements, the authors found significant different effect sizes between conditions. The authors used Hedge's g to determine effect sizes between conditions and found the difference between the objective and subjective loading models to be almost certainly large for the back squat (Hedges' $g = 1.37$) and very likely medium for the bench press. (Hedges' g = 0.98). Based on recent research, practitioners may consider using objective autoregulatory tools to maximize strength outcomes, individualize total training volume, decrease perceived stress or a combination of the three. However, current research is not clear on which loading model may maximize strength outcomes. Thus, more research is needed in this area.

PBT and RPE forms of AR have been shown to be valid, reliable, and effective at improving performance such as strength and hypertrophy. While shown to be effective, PBT may not fully address inherent contextual differences between individuals or exercises and the subjective rating system of RPE may lead to inaccuracies in prescribing appropriate training loads, especially in beginners. VBT has emerged as a novel objective method for autoregulating load prescription. Barbell velocity during movements such as the squat, bench press, and deadlift is an instantaneous objective marker that can provide the coach or athlete real-time feedback about current readiness and have been shown to increase athletic performance (Randell et al., 2011). It is plausible that VBT can be used to explore improvements in resistance training outcomes while potentially mediating the high variability of training adaptations through individualizing the training stimulus to a higher degree than other loading models.

Chapter III: Methodology

The purpose of this study was to explore the effects of three different loading models on strength and body composition in resistance trained persons within a longitudinal quantitative randomized control trial design to address the following research questions:

3.1 Research Questions

RQ1. Is there a significant difference between VBT, PBT, and RPE loading models, pre-post test, for strength improvements.

$H1_0$ There is no significant difference between VBT, PBT, & RPE for strength improvements.

$H1_a$ VBT is a significantly more effective loading model than PBT and RPE for strength improvements.

RQ2. Is there a significant difference between VBT, PBT, and RPE loading models, pre-post test, for body composition improvements.

$H2_0$ There is no significant difference between VBT, PBT, & RPE for body composition changes.

$H2_a$ VBT is a significantly more effective loading model than PBT & RPE for body composition changes.

RQ3. Is there a significant difference between VBT, PBT, & RPE loading model for reducing perceived stress.

$H5_0$ There is no significant difference between VBT, PBT, & RPE for total perceived stress.

$H5_a$ VBT is a significantly more effective loading model than PBT & RPE for reducing perceived stress.

RQ4. Is there a significant difference between VBT, PBT, & RPE loading model to improve perceived recovery status.

$H7_0$ There is no significant difference between VBT, PBT, & RPE for improving perceived recovery status.

$H7_a$ VBT is a significantly more effective loading model than PBT & RPE for improving perceived recovery status.

RQ5. Which loading model demonstrates the least amount of pre-post adaptation variability for maximum strength?

3.2 Operational Definitions

1. Resistance-trained – Having a minimum of 2 years resistance training experience and have regularly trained the back squat, bench press, and deadlift at least 1x/week for the last 6 months.

3.3 Participant Recruitment

3.3a Participants

A total of 23 resistance-trained persons participated in the study, 18 males and 5 females. Inclusion criteria was as follows: over the age of 18, two or more years of resistance training experience, currently free from injury, regularly trained the back squat, bench press, and deadlift exercises the last 6 months, male minimum 1RMs of 120%, 100% 150%, and female minimum 1RMs of 100%, 60%, and 120% for back squat, bench press, and deadlift respectively. Exclusion criteria for the study included the following: less than 18 years of age, less than 2 years of lifting experience, currently injured, unable to meet minimum gender specific 1RM thresholds, currently using anabolic steroids, presenting impaired decision-making abilities, or currently incarcerated.

3.3b Sampling

Upon receiving Seton Hall University Institutional Review Board (IRB) approval (Appendix A), the primary investigator (PI) began the solicitation and recruitment process. The PI employed convenient purposive sampling practices recruiting participants from Multisport Workshop Fitness LLC, local gyms and fitness centers, Facebook, Instagram, and via word of mouth. Specifically, an IRB approved recruitment flyer was posted at the entrance of Multisport Workshop Fitness LLC. The PI reached out to local gyms (Titan Fitness LLC and Snap Fitness LLC) via email with a request to advertise the recruitment flyer. The flyer included the study inclusion and exclusion criteria and provided an overview of the study to ensure potential participants were aware of the study purpose and global procedures. Additionally, the PI recruited participants through the social media platforms Instagram and Facebook which are open to the public for viewing by posting the recruitment flyer. Lastly, participants were recruited through snowball sampling.

3.3c Equipment and Instruments

Equipment for the study included the use of RM-4 Power Racks (Rogue Fitness, Colombus Ohio), 20kg barbells (Rogue Fitness, Colombus Ohio), utility bench (Rogue Fitness, Colombus Ohio), Vitruve Linear Encoders (Vitruve, Spain), assorted free weights (Ivanko Barbell Company, San Pedro California) (Rogue Fitness, Colombus Ohio), Baseline Skinfold

Caliper (Baseline, CO), and Quick Medical Scale (Warwick, RI). Additionally, participants utilized the daily analysis of life demands for athletes (DALDA) and perceived recovery status (PRS) questionnaires. The DALDA is a valid and reliable 32 question assessment of participant's current state (Rushall, 1990). Participants answer each question as "a" better than normal, "b" normal, or "c" worse than normal. Additionally, the PRS a validated questionnaire assessing how well participants expect to perform based on their perceived recovery from prior training bouts (Laurent et al., 2011). The questionnaire utilizes a 0-10 scale with low scores representing poor recovery and anticipated declines in performance while high scores represent better recovery and anticipated improvements in performance.

3.4 Study Procedures

Upon receipt of interest, the PI emailed the IRB approved letter of consent to all potential participants, requesting that they read, sign and return it via email to the PI if they were interested in participating in the study. Upon receipt of the signed letter of consent, which required all participants to self-identify that they met both inclusion and exclusion criteria, the PI emailed each individual participant to schedule an initial meeting for pre-testing at Multisport Workshop Fitness LLC.

Pre-testing:

Participants completed a short paper and pencil demographic questionnaire which asked the following: sex, age, height, body composition, years of training, and current 1RMs (the largest load an individual can successfully complete in accordance with USA Powerlifting (USAPL) rules – (detailed in next section) to determine appropriate training weights (USA

Powerlifting, 2021). After the participant completed the questionnaire, they were asked to remove their shoes and step onto the Quick Medical Scale to record current weight.

Body composition was assessed utilizing Baseline (Baseline, CO) skinfold calipers. Assessment followed the protocol as outlined by the National Strength and Conditioning Association (Baechle & Earle, 2008). Sites assessed were the chest, triceps, subscapular, midaxillary, abdominal, suprailiac, and thigh skinfolds. Skin was dry and measurements were taken prior to exercise. Skin was grabbed between the thumb and index finger to form a “fold” which should include skin and subcutaneous fat (no muscle). The calipers were placed 0.5 – 1.0 inches below the fold. Readings were taken 1-2 seconds after the calipers were placed and read to the nearest 0.5 mm. Two measurements were taken at each site by the PI and the average of the two was recorded. If the first two measurements were not within 3.0 mm, a third measurement was taken and the final two were averaged. Measurements from each site were then entered into a population-specific body density equation (Baechle & Earle, 2008). Body density values were then entered into a population-specific equation for body-fat (Baechle & Earle, 2008).

Prior to 1RM administration participants were instructed by the PI in performing a standardized dynamic warm up involving 10 repetitions of air squats, 10 arm circles, and 10 alternating lunges in place for two rounds. Participants were given an additional 5 minutes to perform any additional warmups they would normally perform in training in order to preserve ecological validity.

The participants were then instructed by the PI on the criteria for the successful execution of the three lifts for the study. The instruction was in accordance with USAPL rules for the back squat, bench press, and deadlift.

Successful Lift Criteria:

Lift 1 (Back Squat): Participants unracked the barbell and had to remain motionless before receiving their squat command. Upon receiving the “squat” command, participants were to squat to a depth in which the hip crease passed below the top of the knee and then returned to an erect position and remained motionless. They then received the “rack” command. Spotters were utilized in accordance with USAPL standards. For the back squat, one spotter (the PI and/or research assistants) assisted on each end of the barbell ready to provide assistance in case of a missed lift.

Lift 2 (Bench Press): Participants unracked the barbell and had to remain motionless with their arms fully extended. Participants were then given “start” command. They were instructed to bring the barbell to the chest and pause at the chest until they received the “press” command. Once the arms were fully extended, they again remained motionless until they received the “rack” command. Spotters were utilized in accordance with USAPL standards. For the bench press, one spotter (the PI and/or research assistants) assisted, standing behind the participant ready to aid in case of a missed lift.

Lift 3 (Deadlift): Participants were instructed to lift the barbell and stand fully erect. Upon standing fully erect participants received the “down” command. In accordance with USAPL standards, a spotter was not provided to assist in the deadlift. In the event of a missed lift, the barbell was placed back on the floor.

Inability to complete a lift, failing to comply with USAPL rules, or receiving assistance from a spotter was deemed a failed lift. Commands and judgement of successful lifts were determined by the PI or research assistant. All attempts were performed with equipment outlined above.

One-repetition maximum (1RM) assessment followed the protocol outlined by Zourdos et al., which used a similar population while assessing the back squat (2016). This involved 5 repetitions at 20%, 3 repetitions at 50%, 2 repetitions at 75%, and 1 repetition at 85% of the participant's self-reported previous 1RMs. Subsequent attempts were selected based upon participant and PI/research assistant communication. Variables considered were a combination of RPE, MCV, and lifters past experiences. Participants were given 3-5 minutes of rest between attempts. This rest included sitting or standing, whichever the participants preferred. A 1RM was established based on 3 criteria: 1. RPE 10 recorded by lifter and PI/research assistant is in agreement, 2. An RPE of 9-9.5 recorded and failed next attempt which increased by 5lbs or less, 3. An RPE of <9 recorded and failed next attempt of 10lbs or less. The order of the lifting was consistent across all participants: back squat, bench press, deadlift.

Throughout 1RM assessment, RPE and MCV data were recorded for each attempt by the PI. MCV data was recorded with the Vitruve linear encoder. For sets with multiple repetitions (the first 3 sets), the highest MCV repetition was recorded. RPE was immediately recorded manually by the PI and transcribed into Microsoft Excel later. Participants had the ability to stop and rest as needed or to stop participating entirely during the pretesting session without any ramifications. The pre-testing session was designed to give the participants experience utilizing both RPE and velocity as they would be randomly assigned to a respective loading model.

Training:

Upon completion of all 1RM assessments, participants were randomly assigned to one of three loading models: VBT, PBT, or RPE. The overarching structure of participants' 8-week periodized plan is outlined by Helms et al (2017). A brief description of the loading models are as follows:

1. VBT – Participants followed a fixed set and repetition scheme. Barbell load was determined as a target velocity range. The PI utilized the MCV data gathered from the 1RM protocol and used a regression analysis to develop an individualized velocity profile. Additionally, participants were assigned a target velocity range ± 0.06 m/s above/below target velocity (Banyard, 2018). Weights on subsequent sets were modified based on performance of the current set. If the participant moved the barbell slower than the target velocity range, the load was reduced 5% of 1RM. If the barbell moved faster than the target velocity range, the load was increased 5% of 1RM.
2. PBT – Participants followed a fixed set, repetition and load scheme as dictated by a percentage of their 1RM.
3. RPE – Participants followed a fixed set and repetition scheme. Barbell load was determined by a target RPE range. Participants were asked to load the barbell with whatever load they felt would achieve a given target RPE range for a given repetition scheme. RPE scores are anchored to how many more repetitions a participant believed they could perform at the conclusion of a set. Subsequent sets were modified based on target RPE. For every 0.5 RPE the participant was above/below the target RPE zone, load was adjusted up or down, respectively, 2% of 1RM (Helms, 2017).

The VBT program has been adapted following the periodized structure outlined by Helms but utilized the velocity-based loading model described by Banyard et al. (2018) and by Orange et al. (2020). Each loading model program can be found in table 4. Participants followed the 8-week loading model under the supervision of the PI and/or research assistants and returned at the end of the 8th week for a follow up body composition and 1RM assessment.

The 8-week loading model required participants training 3 days/week on non-consecutive days. Participants must have completed > 90% of training sessions to remain in the study. This meant any more than 2 missed training sessions resulted in removal from the study. Following the same warmup completed during the assessment, participants performed the back squat, bench press, and deadlift each training day at a given training intensity as outlined in their plan. While participants were encouraged to perform training lifts with the same technical proficiency as during the 1RM assessment, commands and rules were not enforced during training. Throughout the 8 weeks, participants filled out the PRS survey and DALDA questionnaire prior to each training session. Lastly, the PI or research assistant transcribed both MCV (as previously described) and RPE data to Microsoft excel (based on participant feedback) at the conclusion of each set regardless of loading model.

Table 4

Summary of Loading Models

	Percentage-based Training			Rate of Perceived Exertion-based Training			Velocity-based Training		
Week	Monday	Wednesday	Friday	Monday	Wednesday	Friday	Monday	Wednesday	Friday
0	x	x	1RM Testing	x	x	1RM Testing	x	x	1RM Testing
1	2 x 8 @ 65%	2 x 6 @ 70%	2 x 4 @ 75%	2 x 8 @ 5-7 RPE	2 x 6 @ 5-7 RPE	2 x 4 @ 5-7 RPE	2 x 8 @ velocity equivalent 65%	2 x 6 @ velocity equivalent 70%	2 x 4 @ velocity equivalent 75%
2	3 x 8 @ 70%	3 x 6 @ 75%	3 x 4 @ 80%	3 x 8 @ 6-8 RPE	3 x 6 @ 6-8 RPE	3 x 4 @ 6-8 RPE	3 x 8 @ velocity equivalent 70%	3 x 6 @ velocity equivalent 75%	3 x 4 @ velocity equivalent 80%
3	3 x 8 @ 72.5%	3 x 6 @ 77.5%	3 x 4 @ 82x5%	3 x 8 @ 6-8 RPE	3 x 6 @ 6-8 RPE	3 x 4 @ 6-8 RPE	3 x 8 @ velocity equivalent 72.5%	3 x 6 @ velocity equivalent 77.5%	3 x 4 @ velocity equivalent 82x5%
4	3 x 7 @ 75 %	3 x 5 @ 80%	3 x 3 @ 85%	3 x 7 @ 7-9 RPE	3 x 5 @ 7-9 RPE	3 x 3 @ 7-9 RPE	3 x 7 @ velocity equivalent 75 %	3 x 5 @ velocity equivalent 80%	3 x 3 @ velocity equivalent 85%
5	3 x 7 @ 77.5%	3 x 5 @ 82.5%	3 x 3 @ 87.5%	3 x 7 @ 7-9 RPE	3 x 5 @ 7-9 RPE	3 x 3 @ 7-9 RPE	3 x 7 @ velocity equivalent 77.5%	3 x 5 @ velocity equivalent 82.5%	3 x 3 @ velocity equivalent 87.5%
6	3 x 6 @ 80%	3 x 4 @ 85%	3 x 2 @ 90%	3 x 6 @ 8-10 RPE	3 x 4 @ 8-10 RPE	3 x 2 @ 8-10 RPE	3 x 6 @ velocity equivalent 80%	3 x 4 @ velocity equivalent 85%	3 x 2 @ velocity equivalent 90%
7	3 x 6 @ 82.5%	3 x 4 @ 87.5%	3 x 2 @ 92.5%	3 x 6 @ 8-10 RPE	3 x 4 @ 8-10 RPE	3 x 2 @ 8-10 RPE	3 x 6 @ velocity equivalent 82.5%	3 x 4 @ velocity equivalent 87.5%	3 x 2 @ velocity equivalent 92.5%
8	2 x 4@ 80%	2 x 3 @ 85%	1RM Testing	2 x 4@ 6-8 RPE	2 x 3 @ 6-8 RPE	1RM Testing	2 x 4@ velocity equivalent 80%	2 x 3 @ velocity equivalent 85%	1RM Testing

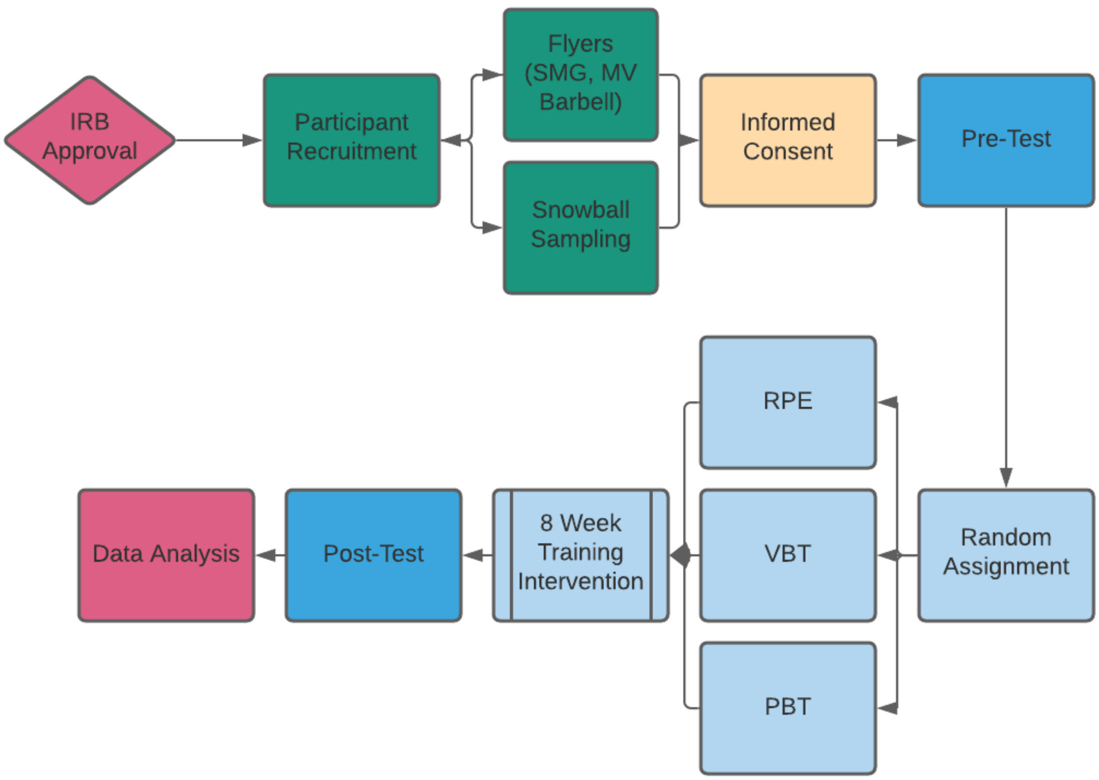
3.5 Data Analysis

Lifting velocities were exported from the Vitruve Linear Encoder Software. Additionally, DALDA and PRS data were exported from Qualtrics into Microsoft Excel. Raw data such as body weight, body composition, 1RMs, and RPEs were manually added to the Microsoft Excel spreadsheet. Once formatted all data was uploaded to SPSS for statistical analysis. A 3x2 factorial analysis of variance (ANOVA) was completed looking at main and interactive effects of the loading models (VBT, PBT, RPE) and time (pre, post) on strength, body weight, and body fat %. A degree of variability existed between loading models for starting strength. Thus, an analysis of covariance (ANCOVA) was performed to evaluate if starting strength as a covariate. A simple analysis of variance (ANOVA) was completed to determine a difference between loading models for PRS. A post hoc Tukey test was performed to examine for significant mean differences. And finally, to address variability, the PI classified high or low training responders as participants that were 1 or more standard deviation above or below the mean response. This was completed for each individual lift, and the total response (summation of all three lifts).

3.6 Visual Overview of Study Procedure

Figure 1

Flowchart of Study Procedure



Chapter IV: Results

The purpose of this study was to explore the effects of three different loading models on strength and body composition in resistance trained persons. Demographic data for participants can be found in tables 5 and 6. Twenty-three participants completed the 8-week intervention with a mean age of 26.48 ± 7.94 years of age and a mean body weight and body fat of 175.65 ± 44.07 lbs. and 18.00 ± 7.75 % respectively.

Table 5

Participants Overall Mean Demographics (n=23)

Age	26.48 ± 7.94
Bodyweight	175.65 ± 44.07
Body fat (%)	18.00 ± 7.75
Training Age (years)	5.56 ± 3.96

Table 6

Participants Overall Mean Demographics by loading model

	PBT	RPE	VBT
Age (years)	28.50 ± 10.51	23.86 ± 4.7	27.14 ± 5.64
Bodyweight (lbs.)	189.51 ± 40.09	177.35 ± 56.21	159.83 ± 12.76
Body fat (%)	20.69 ± 6.67	17.244 ± 6.39	16.18 ±8.83
Training Age (years)	4.75 ± 2.38	4.63 ± 1.80	7.57 ± 5.78

Strength Changes

All loading models saw improvements pre to post in the back squat, bench press, deadlift, and total. Of note, table 7 shows that the largest absolute change for the back squat took place in the RPE loading model, 34.99lbs, while the VBT loading model had the largest relative change, 13.45%. For the bench press exercise, the VBT loading model had the largest absolute and relative change increasing by 15.00lbs and an increase of 8.94% respectively as seen in table 8. The largest absolute change for the deadlift exercise, found in table 9, came from the PBT with an increase of 40.62lbs while the largest relative change took place in the VBT loading model with an increase of 12.93%. The largest absolute changes came from the PBT loading model with an increase of 89.38lbs, while the largest relative change came from the VBT loading model for an increase of 11.94%. Tables 7 through tables 10 show strength data at baseline, post-intervention and total changes for each individual lift as well as combined total changes.

Table 7

Mean Back Squat Changes by loading model

	Loading Model	Mean	Standard Deviation	n	Absolute Change	Relative Change
Pre Squat	PBT	330.64	118.33	8		
	RPE	316.25	118.13	8		
	VBT	255.71	50.78	7		
	Total	302.83	103.21	23		
Post Squat	PBT	365.63	134.76	8	34.99	10.23%
	RPE	352.50	126.87	8	36.25	12.00%
	VBT	290.71	61.27	7	35	13.45%
	Total	338.26	113.97	23	35.43	11.89%

Table 8

Mean Bench Press Changes by loading model

	Loading Model	Mean	Standard Deviation	n	Absolute Change	Relative Change
Pre Bench	PBT	218.75	85.68	8		
	RPE	201.25	74.96	8		
	VBT	182.86	32.90	7		
	Total	201.74	68.10	23		
Post Bench	PBT	232.50	94.87	8	13.75	5.86%
	RPE	215.63	77.94	8	14.38	7.25%
	VBT	197.86	31.07	7	15	8.94%
	Total	216.09	72.55	23	14.35	7.35%

Table 9

Mean Deadlift Changes by loading model

	Loading Model	Mean	Standard Deviation	n	Absolute Change	Relative Change
Pre Deadlift	PBT	379.38	150.68	8		
	RPE	356.25	111.09	8		
	VBT	307.14	73.87	7		
	Total	349.35	116.41	23		
Post Deadlift	PBT	420.00	155.31	8	40.62	11.39%
	RPE	392.50	133.50	8	36.25	9.42%
	VBT	345.71	79.71	7	38.57	12.93%
	Total	387.83	126.60	23	38.48	11.25%

Table 10

Overall Mean Total Changes by loading model

	Loading Model	Mean	Standard Deviation	n	Absolute Change	Relative Change
Pre Total	PBT	928.75	347.24	8		
	RPE	873.75	298.23	8		
	VBT	745.71	147.01	7		
	Total	853.91	280.11	23		
Post Total	PBT	1018.13	378.05	8	89.38	9.56%
	RPE	960.63	327.75	8	86.88	9.83%
	VBT	834.29	163.97	7	88.58	11.94%
	Total	942.17	304.81	23	88.26	10.45%

Difference Testing for Strength

A 3x2 factorial analysis of covariance (ANCOVA) found no significant strength differences for the back squat, bench press, deadlift, or total variables between loading models, while significant time interactions were observed indicating all loading models increased strength. Back squat and total strength showed significant interactive effects between time and starting strength. Table 11 illustrates differences within and between loading models for strength changes on the squat, bench press, deadlift, and total variables.

Table 11

Test of Within and Between Loading Model Changes for Strength

	Squat		Bench Press		Deadlift		Total	
	ANOVA	*ANCOVA*	*ANOVA*	*ANCOVA*	*ANOVA*	*ANCOVA*	*ANOVA*	*ANCOVA*
Time:	<.001*	.727	<.001*	.751	<.001*	.437	<.001*	.599
Time*Starting Strength		.004*		.083		.306		.016*
Loading Model	.398	.616	.645	.823	.517	.947	.487	.774

Note. * denotes statistical significance

Body Composition Changes

On average, every loading model gained weight over the course of the 8-week intervention. The VBT loading model gained the most total weight and had the largest relative change in weight at 3.14lbs. and 1.93% respectively. On average every loading model had a decrease in body fat % with the RPE loading model having the largest decrease at 0.77% (absolute change). Tables 12 and 13 display body composition changes for each loading model and the mean changes for all participants across loading models.

Table 12

Body Weight Changes

	Loading Model	Mean	Standard Deviation	n	Absolute Change	Relative Change
Pre BW	PBT	189.51	43.30	8		
	RPE	177.35	60.10	8		
	VBT	159.83	13.78	7		
	Total	175.65	44.07	23		
Post BW	PBT	192.07	49.58	8	2.56	0.83%
	RPE	179.73	60.49	8	2.38	1.40%
	VBT	162.97	14.94	7	3.14	1.93%
	Total	178.32	46.13	23	2.67	1.39%

Note. BW = body weight.

Table 13

Body Fat Changes

	Loading Model	Mean	Standard Deviation	n	Absolute Change
Pre Body Fat %	PBT	20.69	7.20	8	
	RPE	17.24	6.83	8	
	VBT	16.18	9.54	7	
	Total	18.00	7.75	23	
Post Body Fat %	PBT	20.41	8.22	8	-0.28
	RPE	16.47	6.98	8	-0.77
	VBT	16.12	9.13	7	-0.06
	Total	17.61	7.95	23	-0.39

Overall, there were no significant differences between loading models for body composition changes. Table 14 illustrates between loading model differences for body composition.

Table 14

Test of Within and Between Loading Model Changes for Body Composition

	Body Weight		Body Fat %
	ANOVA	ANCOVA	ANOVA
Time:	.020*	.207	.238
Time*Loading Model	.954	.062	.605
Loading Models	.493	.715	.546

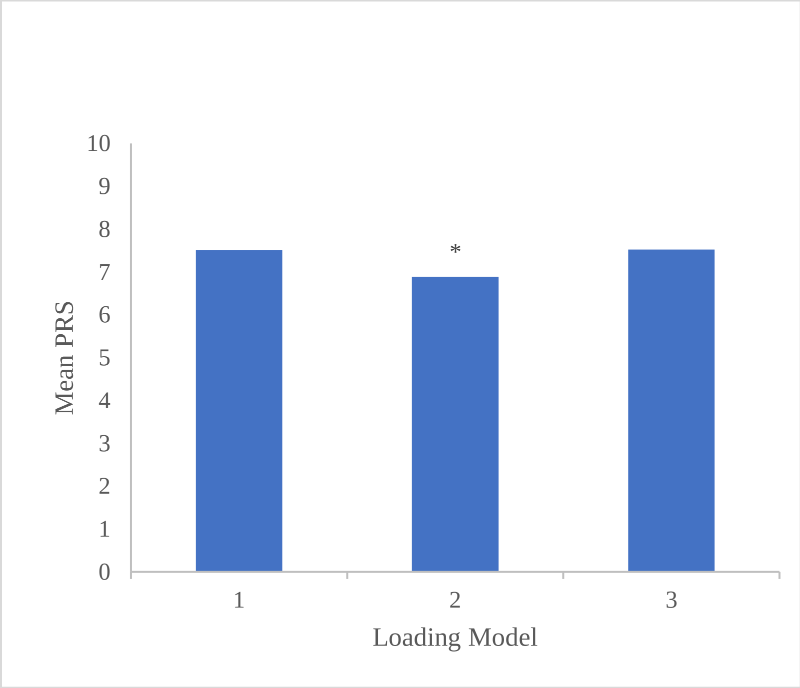
Note. * denotes statistical significance

Mean Perceived Recovery Status

A secondary aim of our study was to determine if manipulating the loading model had an effect on PRS. The VBT loading model displayed the lowest PRS with a mean score of 6.89, while the PBT and RPE models scored 7.51 and 5.53 respectively. A significantly lower PRS score was found between loading models, p = .004. A post hoc analysis found the VBT loading model perceived their recovery status to be significantly less on average than both the RPE and PBT loading models. Figure 2 illustrates the mean recovery status scores for each loading model.

Figure 2

Mean PRS Scores Between Loading Models



Note. * denotes significant changes

Note. 1 = RPE, 2 = VBT, 3 = PBT

Variability of Response

The final aim of this study was to understand the impact of a loading model on the variability of response in resistance trained persons. The largest response to the training intervention for the back squat, bench press, and deadlift came from the RPE, VBT, and VBT loading models respectively. Accordingly, the lowest responders came from the RPE, PBT, and RPE loading models respectively. When looking at the total relative change variable, a participant from the RPE loading model exhibited the largest relative change (21.99%). Interestingly, Figure 6 shows the smallest relative change (3.64%) also came from the RPE loading model. Figures 2 through 5 demonstrate the variability of response for each participant for each strength-based variable (squat, bench press, deadlift, and total).

Figure 2

Relative Squat Change & Variability of Response

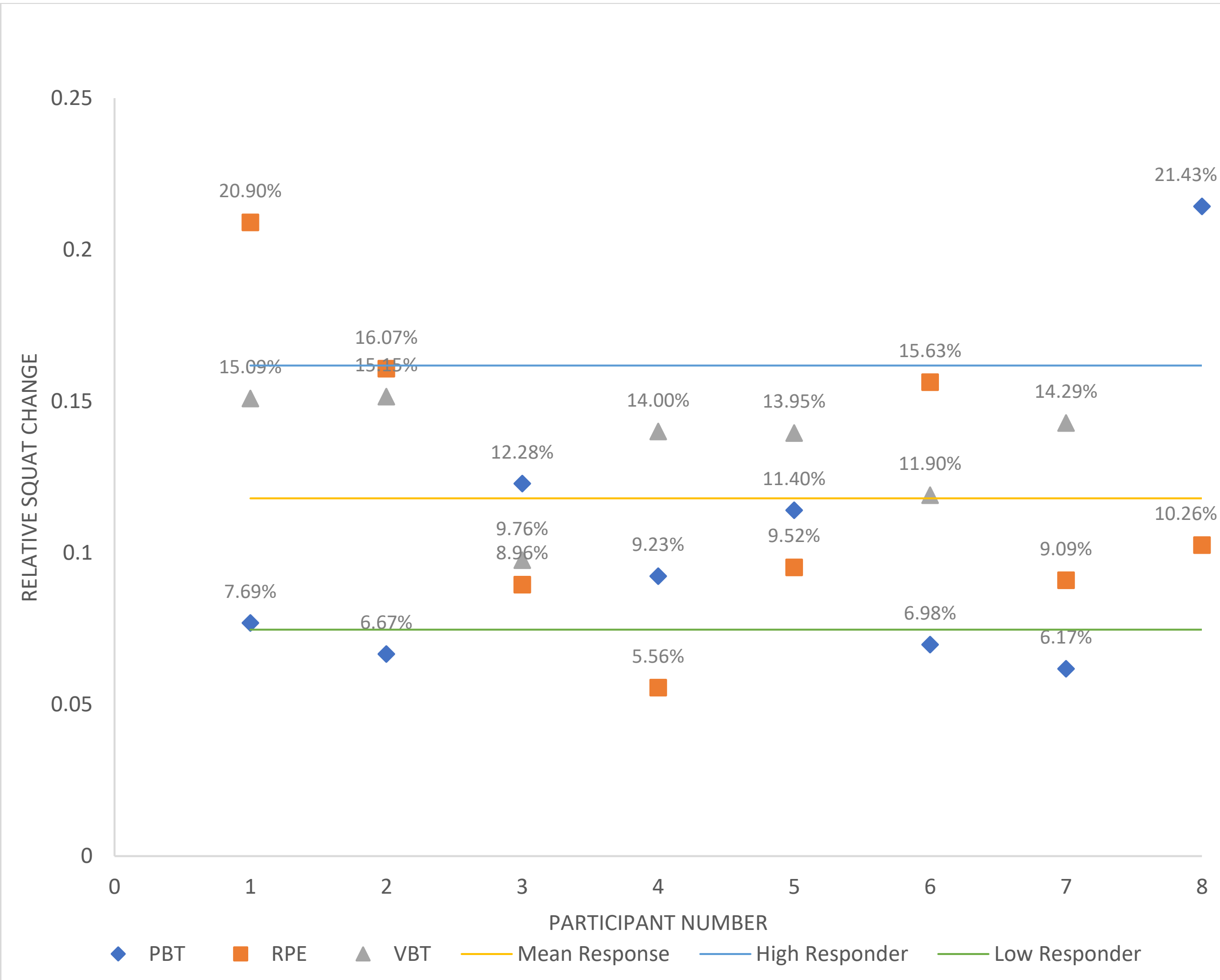


Figure 3

Relative Bench Change & Variability of Response

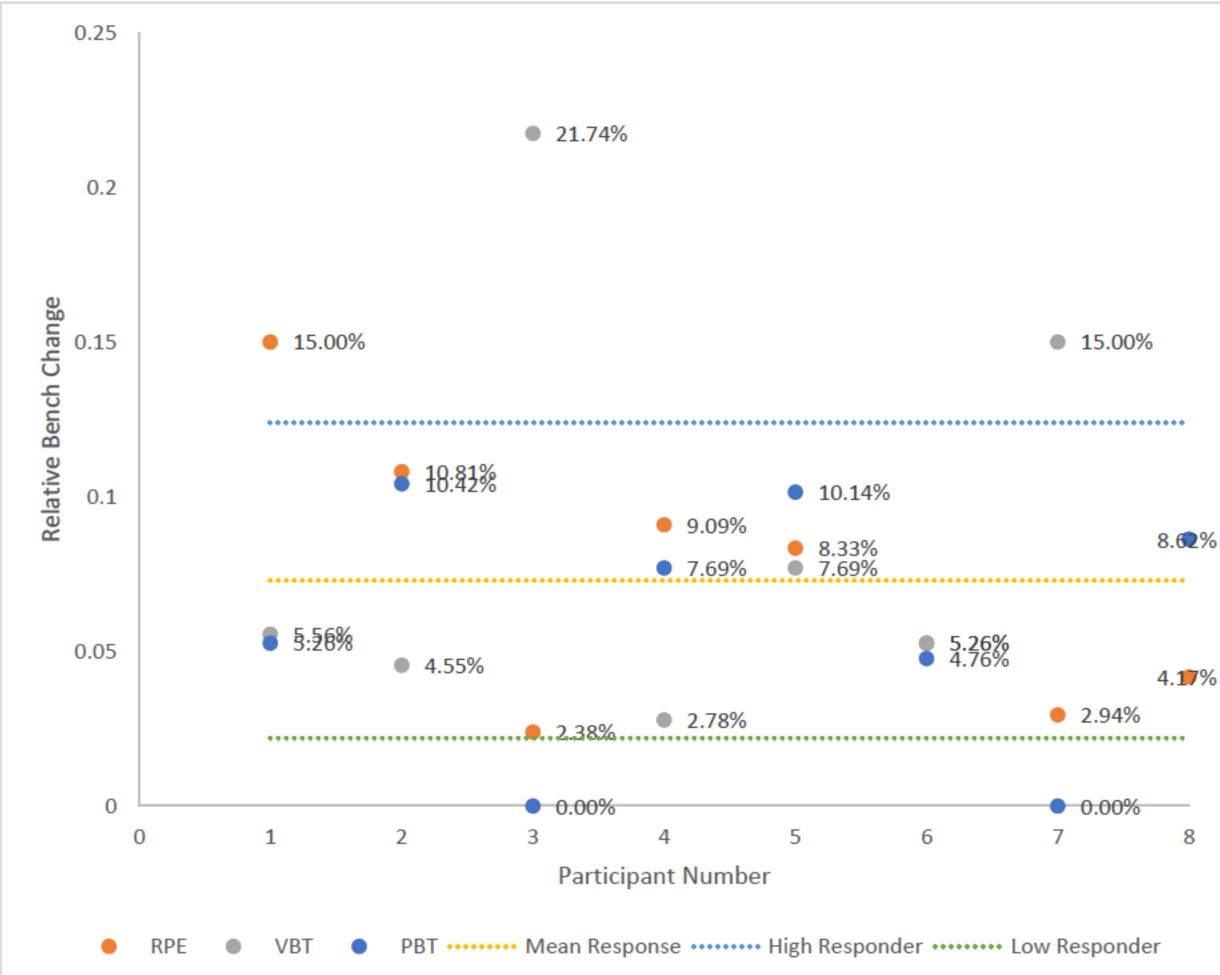


Figure 4

Relative Deadlift Change & Variability of Response

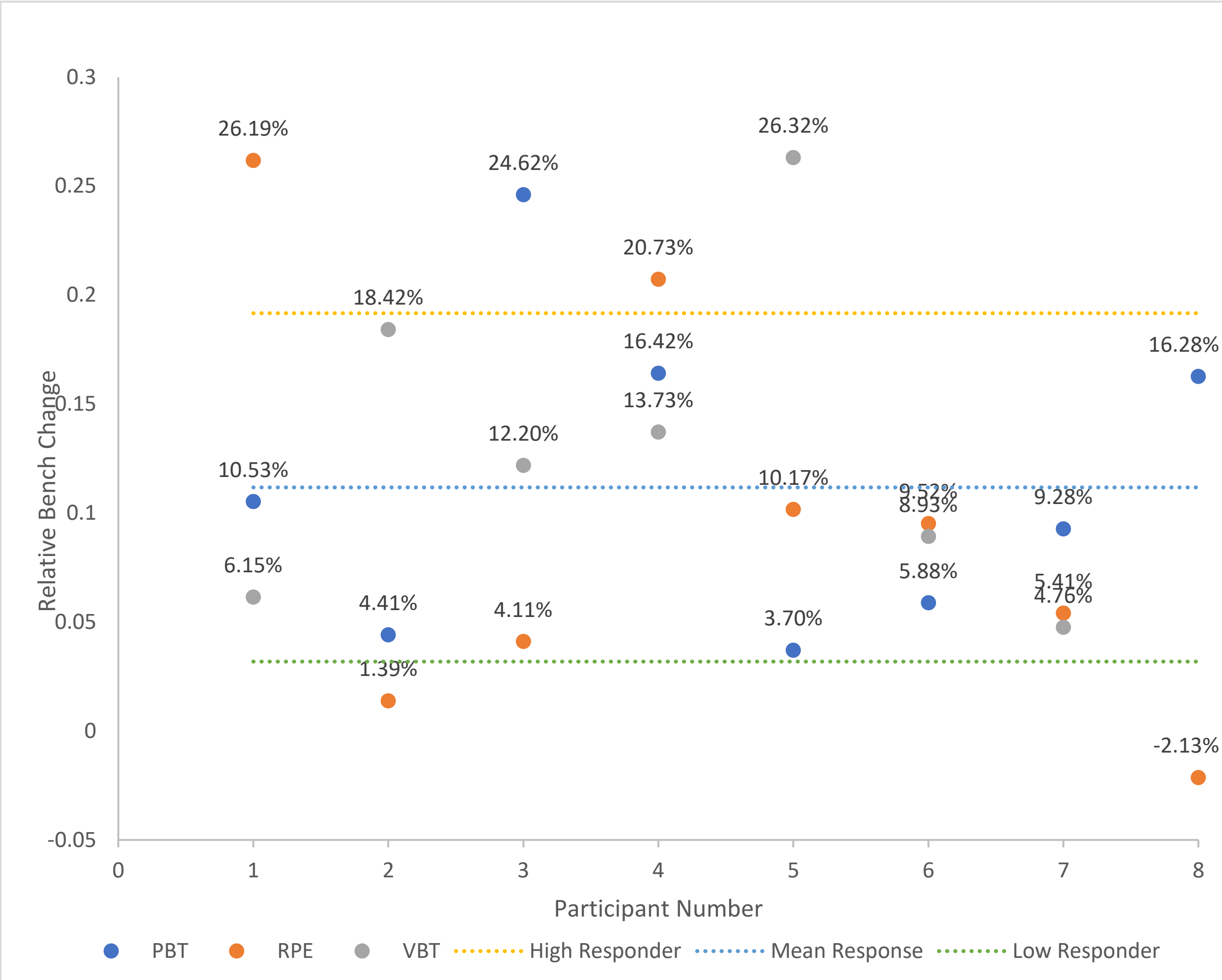
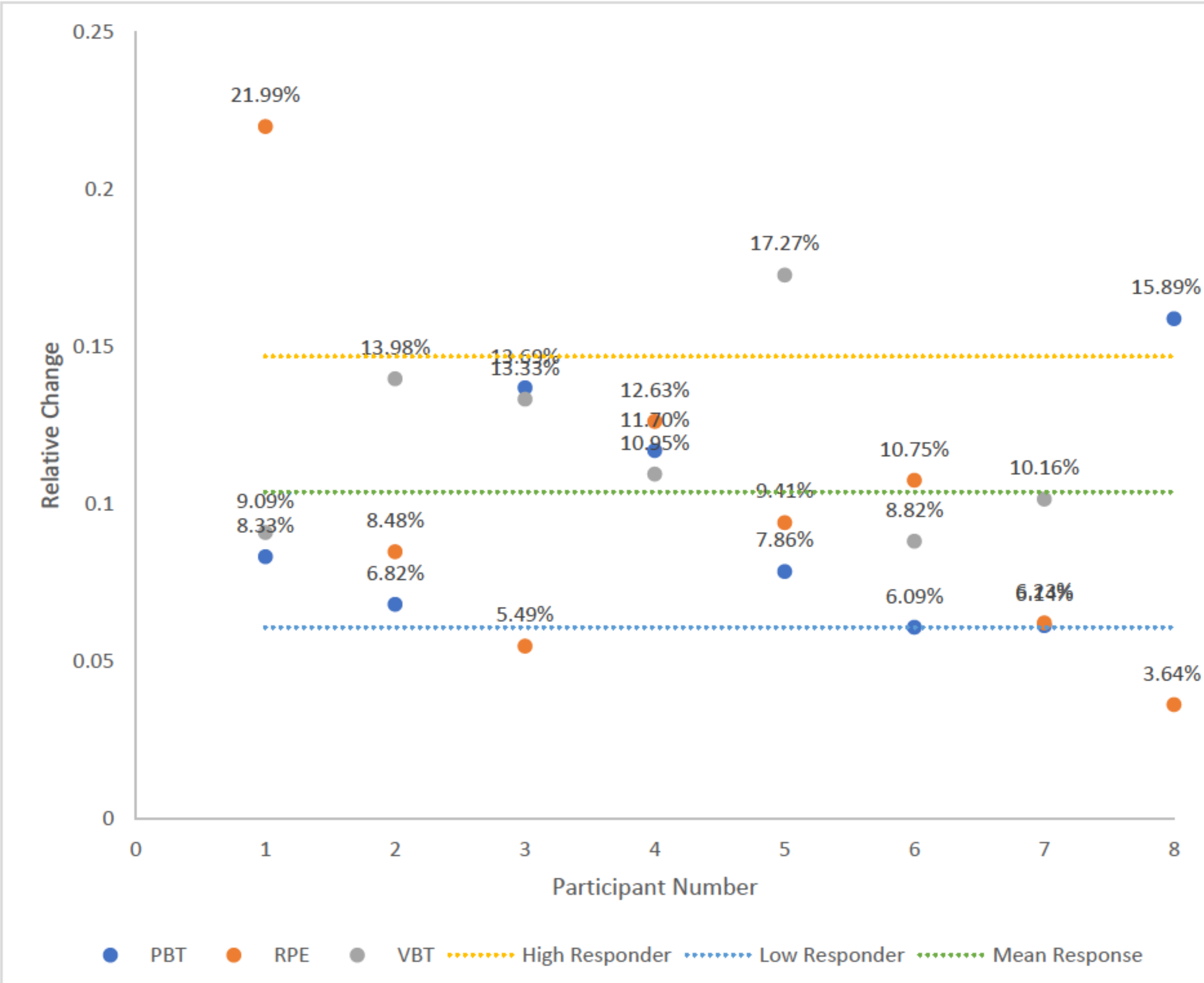


Figure 5

Relative Total Change & Variability of Response



Comparison of RPE Between Loading Models

Table 15 displays the descriptive statistics for total mean RPE scores between loading models across the 8-week intervention. RPE was found to be significantly different between loading models as shown in table 16. The RPE loading model trained at a higher RPE on average when compared to both the PBT and VBT loading models. On average, across all three lifts, the weekly mean RPE score was higher for the RPE loading model than the other models every week (weeks 1-8). Statistically significant differences were observed at weeks 4, 5, 6, and 7 as displayed in figure 7.

Table 15

Mean RPE by Loading Models

	Loading Model	Mean	Std. Deviation	n
RPE	PBT	6.74	1.14	8
	RPE	7.59	1.10	8
	VBT	6.43	1.05	7
	Total	6.94	1.10	23

Table 16

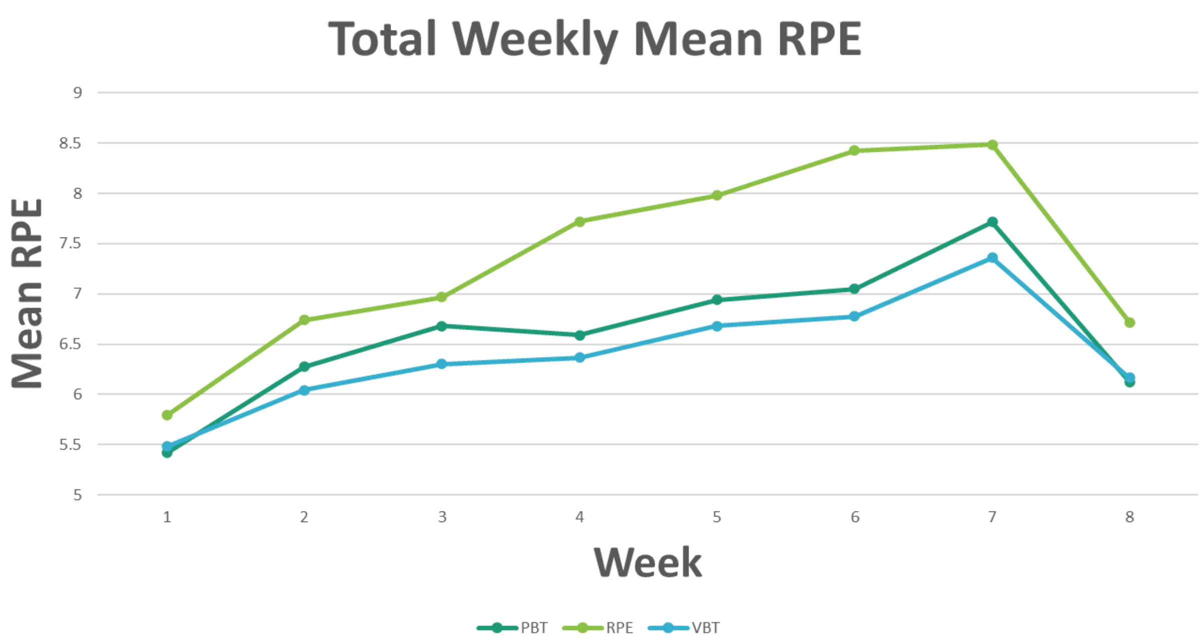
Test of Between Loading Model Changes for Total RPE (Mean weeks 1-8)

	Sum of Squares	df	Mean Square	F	Sig.
Between Loading Models	4.773	2	.238	7.896	.003*

*Note. * denotes statistical significance*

Figure 6

Total Weekly Mean RPE



Chapter V: Discussion

Strength

Our findings did not demonstrate a significant difference between loading models for strength when looking at individual lifts or summated total strength. One potential explanation for this finding is the matched sets and repetitions protocol used within the study. Research suggests a dose-response relationship exists for volume and strength (Ralston et al, 2017). As the present study matched sets and repetitions, training volumes were similar across loading models and ultimately may have contributed to the similar strength adaptations. A secondary explanation for the similar findings could be that the RPE between loading models was relatively similar. Recent research has suggested that monitoring proximity to failure (via velocity-loss) can improve strength outcomes (Pareja-Blanco et al., 2020). However, an exact proximity to failure to maximize strength outcomes remains unclear. Instead, a range of repetitions until failure may be a more practical nuance when structuring resistance training programs. For example, Androulakis-Korakakis et al. recommended powerlifters looking to improve strength over the course of 6-12 weeks to train between an RPE range of 7-9.5 for their main exercises and accessory lifts (2021). Within the present study the mean total weekly RPE was significantly higher in the RPE loading model for weeks 4-7. However, each loading model may have been sufficiently close to failure and thus similarly enhanced strength outcomes.

The present findings on strength between loading models are partially supported in the literature (Helms et al., 2018; Orange et al., 2020; Zhang et al., 2023). In 2018, Helms et al. did not find a significant difference in strength between RPE and PBT loading models when looking at resistance trained males over the course of 8 weeks. Similarly, Orange et al. found that a VBT loading model was similarly effective at improving lower body strength assessed via the back squat when training 2x/week (2020). Lastly, Zhang et al. found no significant differences in 1RM strength on the back squat and bench press between VBT and PBT loading models over the course of a 6-week training intervention in 15 collegiate female basketball players (2023).

Body Composition

Comparatively less literature exists comparing the impact of autoregulatory loading models on body composition. The present study did not find significant differences between loading models specifically for body weight and body fat percentage as assessed via skinfold calipers. These findings are in agreement with Helms et al. who found no significant difference in muscle thickness in the pectoralis major and vastus lateralis assessed via ultrasonography (2018). As both Helms et al. and the present study matched total training volume, the similar hypertrophic response is to be expected based on our current understanding of volume and muscular hypertrophy which shows a dose-response relationship (Schoenfeld et al., 2017). Based on this understanding, autoregulatory loading strategies which manipulate volume-load and/or proximity to failure could provide a potential benefit for increases in muscle mass. For example, researchers have manipulated volume using a velocity-loss method which involves the cessation of a set based on a specified relative loss in velocity. Pareja-Blanco et al. found a larger velocity-loss threshold increased hypertrophy of the quadricep when compared to a lesser velocity-loss threshold (2017). This autoregulatory method could increase/decrease total training volume based on the size of the velocity-loss threshold. However, research on equating volume-load is conflicting as other researchers have found total training sets (performed reasonably close to failure) may be a more important predictor of muscular hypertrophy (Refalo et al., 2023). Further research on autoregulating volume-load, total training sets, and proximity to failure on body composition is warranted.

Athlete Readiness by Loading Model

The present study found a significantly lower PRS score within the VBT loading model when compared to the PBT and RPE models. One potential explanation for this decreased perception of recovery is an increased neurological demand from the VBT training. While direct comparisons for barbell velocity were not made in the present study, it is plausible that the VBT loading model moved faster on average. Research has shown that increased barbell velocities can increase neuromuscular demand. Specifically, faster concentric repetitions have been shown to elicit earlier EMG activity, increase in maximal firing rate frequency, and increased recruitment of fast twitch muscle fibers (Pareja-Blanco et al., 2014; Van Cutsem et al., 1998). This increased neuromuscular demand may have decreased readiness to train. Additionally, this may indicate an increased need for a training deload and/or taper. This could be especially important when attempting a physiological peak when implementing autoregulatory methods as others have suggested (Helms et al., 2018). Lastly, it is possible the VBT loading model forced participants to train at a challenging load within their target velocity zone despite a potential decrease in readiness. Comparatively, the RPE loading model allowed participants to adjust load based on a subjective marker. The subjectivity of the RPE loading model may have allowed participants to train at a lesser relative weight if they did not feel 100%. The PBT loading model is an objective model and did not adjust relative intensity based on improving fitness which could explain the higher PRS scores from the PBT loading model.

Contrary to the present study, prior research showed an increase in perceived recovery when comparing a VBT loading model to a PBT loading model (Orange et al., 2020). One explanation for these conflicting findings is the present study utilized a 3x/week training frequency vs 2x/week and the use of 9 velocity-based sets per session vs 4 velocity-based sets per session. When considering the potential for increased neuromuscular demand, it is possible that the training volume in the present study, 27 velocity-based sets per week, decreased perceived readiness between sessions more than prior research which implemented 8 velocity-based sets per week.

Variability of Responsiveness by Loading Model

Despite a relatively homogeneous mean response between loading models in the present study, a closer look reveals some interesting variability at the individual level for strength. The RPE loading model had the greatest number of high responders, totaling 6 across the back squat, bench press, deadlift, and total. The PBT loading model had the greatest number of low responders, 6. Interestingly, VBT demonstrated the least number of low responders, 1, while also having the smallest range of responses when looking at the total. The greatest total increase came from the RPE loading model with an increase of 21.99%. Surprisingly, the RPE loading model also had the two smallest total increases, 3.64% and 5.49%. This diverse spectrum of responses in part may explain why the RPE loading model has a similar mean response to the other loading models. A few potential conclusions can be drawn; The VBT loading model, as outlined within the prior section, were forced to train at a minimum load to remain within their target velocity zone every session despite a decrease in PRS. This provided an objective target to ensure participants always trained at a theoretically sufficient intensity. However, at the other end of the spectrum, participants within the VBT loading model were "capped" at selecting a load to ensure they remained within their target velocity zone. Despite some participants feeling they could go up in load, their target velocity zone did not allow it. While having the widest range of outcomes, the RPE loading model did have the single best response for strength. A potential explanation for this best response is the "soft-capped" nature of the RPE loading model. If a participant is feeling good, the load may go up as much as desired provided it remains within the target RPE zone. The perceptual aspect of the RPE loading model appears to be more of a soft cap on load when compared to the other loading models in the author's opinion. The soft cap may also explain the RPE loading model having the lowest responders. Some participants appeared to rate their RPE based on their desire to change the load on the barbell. Some participants appeared to not want to increase load which can be connected to our final conclusion regarding variability. It is possible that a specific loading model may be more appropriate for a participant based on psycho-social characteristics. For example, an inherently competitive person may be more suited to the VBT loading model due to the objective feedback and wanting to "beat" prior sets or prior days velocities. Additionally, other participants may enjoy the structured nature of the PBT loading model that is planned out for the entirety of a training block. Very little mid-session thinking is required when compared to VBT or RPE loading models. Future research matching loading models and psycho-social characteristics is warranted. Based on the current data, it is possible that a VBT loading model may provide the least amount of variability in the adaptative response for strength while an RPE loading model may be able to provide the greatest ability to capitalize on fluctuating strength levels because of its relatively soft-capped nature.

Limitations

Several limitations of the present study exist. First, ecological validity of the loading models within the present study may be lower than independent use of the loading models as each group did use both RPE and velocity to draw comparisons. The use of a velocity encoder or RPE may have increased motivation, force production and/or increased awareness regarding current fatigue. For example, Weakley et al. found increased barbell velocity, motivation, competitiveness, and perceived workload when providing real-time velocity feedback as compared to no feedback (2019). While participants of the present study were not provided with real-time feedback between each repetition, the researchers did find some participants observing their velocity between sets regardless of assigned loading model. Future research may benefit from having participants be blinded to the intervention and reported data. Another limitation of the present study is a lack of control for sleep and nutritional control/reporting. It is well understood that sleep, caloric intake, and protein intake/timing can impact recovery, strength, and body composition changes (Helms et al., 2014; Kerksick et al., 2017; Roy et al., 2000; Rozenek et al., 2002). Additionally, while inclusion criteria were met to reserve the findings of the present study for resistance trained populations, there were wide differences in both experience and strength among participants. For example, one male participant began the study with a 570lb squat, 345lb bench, and a 675lb deadlift while two males started the study with back squat ≤ 215, bench press ≤ 195, and a deadlift ≤ 285. Future research may better elucidate true changes with more targeted inclusion/exclusion criteria.

Lastly, DALDA assessment scores could not be used to draw conclusions within the present study due to poor survey adherence. Future research with daily monitoring of DALDA scores may provide valuable insight into daily fluctuations in individual readiness to train. This could be a strong indicator of the variable adaptive response.

Practical Application

In all research on autoregulatory loading models, no significant difference or a positive effect on strength adaptations has been observed when compared to traditional PBT loading model. Potential benefits from autoregulatory loading models include training at higher relative intensities, training at a closer proximity to failure, and increased motivation. Thus, autoregulatory loading models may provide a benefit, particularly to experienced lifters which may require increased exposure to higher relative training loads (>80%).

Future Research

The present study examined resistance trained persons with a minimum of 2 years of lifting experience. Future research might benefit from more restrictive inclusion/exclusion criteria in order to draw conclusions about specific populations. For example, powerlifters, team-sport athletes, and recreational lifters all may have had sufficient lifting experience and strength to partake in the present study. However, their contextual backgrounds, goals, and external stressors may potentially affect training outcomes. Additionally, at this point in time, all three loading models appear to be effective at improving both strength and body composition in resistance trained persons. Yet, it may be possible that one loading model is more appropriate for a specific psycho-social profile. For example, some lifters may enjoy the fixed structure and organization of the PBT model as it requires little effort on the part of the lifter. An RPE model requires a person to take time to prospectively gauge their strength to select loads, log RPE after each set, and finally adjust subsequent loads. This may not be appropriate for the lifter looking for structure and simplicity. Similarly, VBT loading models require an individualized velocity target zone based on a load velocity profile and for participants to also prospectively adjust load. Each autoregulatory loading model requires more effort and/or preparation than a simple PBT loading model. While some lifters look for simplicity, others look for, other lifters may enjoy the competitiveness of "beating" their velocity zones. Therefore, developing a tool to assign a loading model based on inherent psychological profiles may enhance the efficacy of a loading model.

Conclusion

Training with an appropriate load is an integral component for resistance trained populations to enhance both strength and body composition. The traditional PBT loading model may be inappropriate based on on-going training adaptations, interparticipant differences, and inter-exercise differences. Both RPE and VBT loading models can serve as viable alternatives to a PBT loading model while producing similar group strength responses. On an individual level, autoregulatory loading models may be able to maximize adaptations based on fluctuating strength levels as well as reduce the number of low responders.

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Appendices

Appendix A: IRB Approval

SETON HALL UNIVERSITY
1856

04/26/2022

Orlando Rivera
Seton Hall University

Re: Study ID# 2022-305

Dear Orlando,

The Research Ethics Committee of the Seton Hall University Institutional Review Board reviewed and approved your research proposal entitled "Effects of three different loading protocols on strength and hypertrophy in resistance trained persons" as resubmitted. This memo serves as official notice of the aforementioned study's approval as exempt. Enclosed for your records are the stamped original Consent Form and recruitment flyer. You can make copies of these forms for your use.

The Institutional Review Board approval of your research is valid for a one-year period from the date of this letter. During this time, any changes to the research protocol, informed consent form or study team must be reviewed and approved by the IRB prior to their implementation.

You will receive a communication from the Institutional Review Board at least 1 month prior to your expiration date requesting that you submit an Annual Progress Report to keep the study active, or a Final Review of Human Subjects Research form to close the study. In all future correspondence with the Institutional Review Board, please reference the ID# listed above.

Thank you for your cooperation.

Sincerely,

Mara Podvey
Mara C. Podvey, PhD, OTR
Associate Professor
Co-Chair, Institutional Review Board

Phyllis Hansell
Phyllis Hansell, EdD, RN, DNAP, FAAN
Professor
Co-Chair, Institutional Review Board

Office of the Institutional Review Board
Presidents Hall · 400 South Orange Avenue · South Orange, New Jersey 07079 · Tel: 973.275.4654 · Fax 973.275.2978 · www.shu.edu
WHAT GREAT MINDS CAN DO

Appendix B: Solicitation Letter & Informed Consent

Dear Prospective Participant,

My name is Orlando Rivera. I am a PhD student in Department of Interprofessional Health Sciences and Health Administration, School of Health and Medical Sciences at Seton Hall University. I am conducting a research study as part of my doctoral dissertation. **I am inviting you to please read the information below about my study and am asking you to please forward this letter of solicitation to any potential participants which fit my criteria for inclusion.**

Title of Research Study: Effects of three different loading protocols on strength and hypertrophy in resistance trained persons.

Principal Investigator/Doctoral Student: Orlando Rivera, MS, CSCS

Principal Investigator Faculty Advisor/Dissertation Chair: Genevieve Pinto Zipp, PT, EdD, FNAP

Research Assistants: Robert Schepis BS, SDPT

Kyle Mitchella BS, CSCS, SDPT

Department Affiliation & Sponsor: Department of Interprofessional Health Sciences and Health Administration, School of Health and Medical Sciences

Purpose of the research study: The purpose of this study is to explore the effects of three different loading protocols, velocity-based training (VBT), percentage-based training (PBT), and rating of perceived-based training (RPE) on strength and hypertrophic outcomes in resistance trained persons.

Brief summary about this research study:

The following summary of this research study is to help you decide whether or not you want to participate in the study. You have the right to ask questions at any time. The risks for participating in this study are minimal. ***Potential risks include potential muscle soreness and discomfort, decreased confidence, and decreased self-efficacy.***

This study is looking at the effects of three different loading protocols on strength and muscle gain(hypertrophy) in resistance trained persons. As a potential participant, you will have to go through a 1 repetition maximum (1RM) for the back squat, bench press, and deadlift and body composition assessment. You will then be given an 8-week training plan involving 1 loading protocol, VBT, PBT, or RPE. You will be asked to follow the program under my supervision or the supervision of a research assistant at Multisport Workshop LLC, located at 27 Holt Dr. Stony Point, NY. You would be required to train 3 days/week on non-consecutive days for 8 weeks straight (Ex: Mon., Wed., Fri.). After completing the final session of the 8-week training protocol, you will be asked to complete a second 1RM and body composition assessment.

Inclusion and exclusion criteria:

You are being asked to participate in this study because you are an experienced resistance trained person (2 years or more). You should also have training maximums of 1.5x your bodyweight for the back squat and deadlift, and 1.25x your bodyweight for the bench press as a male. Females should have training maximums of 1.25x, 0.75x, and 1.25x your bodyweight respectively. We ask that participants have been trained the back squat, bench press, and deadlift at least 1x week for the last 6 months, are recently free from injury and are able to speak and read English.

Exclusion criteria for this study is having a planned sporting competition during the duration of this study, having less than 2 years training experience, having not trained regularly for the last 6 months, 1RMs less than 1.5x/1.25x bodyweight for the squat and deadlift and less than 1.25x0.75x bodyweight for the bench press for males/females respectively, currently injured, use of anabolic steroids, pregnant women, not able to read/understand/speak English, < 18 years of age, currently incarcerated, or individuals with impaired decision making capacities.

Participation duration:

Your anticipated duration for this study is 9 weeks. This includes 1RM and body composition assessment followed up with an 8 week periodized training plan. This will then be followed up with a second 1RM and body composition assessment. The initial assessment visit be approximately 90-120 minutes in length. Training sessions at Multisport Workshop Fitness LLC, Stony Point, NY, should be approximately 90-120 minutes in length each day 3x/week for 8 weeks. The final assessment day should be approximately 90-120 minutes in length.

Procedures to be followed:

Should you choose to participate in this study you will be asked to visit Multisport Workshop Fitness LLC, 27 Holt Dr. Stony Point, NY, for an initial assessment and familiarization process.

Pre-testing involves first gathering your information: gender, age, height, body weight, body composition, years training, and current 1RMs (the largest load an individual is able to successfully complete in accordance with USAPL rules) to determine appropriate training weights. Body weight will be assessed via a Quick Medical Scale. Body composition will be assessed utilizing Baseline skinfold calipers. Assessment will follow the protocol as outlined by the National Strength and Conditioning Association. Sites being assessed are chest, triceps, subscapular, midaxillary, abdominal, suprailiac, and thigh skinfolds. Skin is to be dry and measurements are taken prior to exercise. Skin is grabbed between the thumb and index finger to form a “fold” which should include skin and subcutaneous fat (no muscle). The calipers are placed 0.5 – 1.0 inches below the fold. Readings are taken 1-2 seconds after the calipers are placed and read to the nearest 0.5 mm. Two measurements are taken at each site and the average of the two is recorded. If the first two measurements are not within 3.0 mm, a third measurement is taken and the final two are averaged. Measurement from each site will then be entered into a population-specific body density equation. Body density values are then entered into a population-specific equation for body-fat.

Prior to 1RM administration you will perform a standardized dynamic warm up involving 10 repetitions of air squats, 10 arm circles, and 10 alternating lunges in place for two rounds. You will be given an additional 5 minutes to perform any additional warm ups you normally perform.

1RM assessment criteria be in accordance with USAPL rules for the back squat, bench press, and deadlift. For the back squat you must unrack the barbell and remain motionless before receiving your squat command. Upon receiving the "squat" command, you are to squat to a depth in which the hip crease passes below the top of the knee and then return to an erect position and remain motionless. You will then receive the "rack" command. For the bench press you must unrack the barbell and remain motionless with the arms fully extended. You will be given the "start" command. You must then bring the barbell to the chest and pause at the chest until you receive the "press" command. Once the arms are fully extended, you must again remain motionless until you receive the "rack" command. For the deadlift, you must lift the barbell and stand fully erect. Upon standing fully erect you will receive the "down" command. Inability to complete a lift, failing to comply with USAPL rules, or receiving assistance from a spotter will be deemed a failed lift. All commands and judgements will be given by the PI (Orlando Rivera) or research assistant (Robert Schepis). Spotters will be provided.

The 1RM ramp up protocol is as follows: 5 repetitions at 20%, 3 repetitions at 50%, 2 repetitions at 75%, and 1 repetition at 85%. Subsequent attempts will be selected based upon your feedback and the PI or research assistants' communication and will be based on a combination of RPE, lifting velocity, and lifters past experiences. You will be given 3-5 minutes between attempts. A 1RM is established based on 3 criteria: 1. RPE 10 recorded by lifter and PI/research assistant is in agreement, 2. An RPE of 9-9.5 recorded and failed next attempt which increased by 5lbs or less, 3. An RPE of <9 recorded and failed next attempt of 10lbs or less. This will be completed for the squat first, followed by the bench press. The deadlift 1RM will be performed last.

You will then be randomly assigned to a specific loading protocol, VBT, PBT, or RPE. Your training loads will be dictated by your specific assignment. VBT will assign you a specific target velocity range. The PI/research assistant will recommend loads that enable you to train within the given target velocity. If the barbell is moving faster than the target velocity, barbell load will be increased by 5% on the subsequent set. If the barbell is moving below the target velocity, the barbell load will be decreased by 5% on the subsequent set. For PBT, barbell load will be determined as a specific percentage of your 1RM. Lastly, for RPE, you will be given a target RPE for the day. RPE will be associated with how many more reps you believe you can perform at the conclusion of a set and based on a 1-10 scale. For example, an RPE of 10 equates to 0 more repetitions in reserve. An RPE of 9 equates to 1 more repetition in reserve, etc. The PI/researcher assistant will recommend loads that target your assigned RPE. If your true RPE is above the target RPE, the load will be reduced by 2% on the subsequent set. If your true RPE is below your target RPE, loads will be increased by 2% on the subsequent set. You will be given information regarding your training loads, rest periods, and training frequency for the next 8 weeks. You are to train on non-consecutive days and must complete > 90% of training sessions to remain included in the study. This means any more than 2 missed training sessions will result in removal of the study. You will also be educated on how to fill out a daily analyses of life demands (DALDA) and perceived recovery status (PRS) form. The DALDA is a brief 32 question assessment of your current state. You answer each area as "a" better than normal, "b" normal, or "c" worse than normal. Examples of areas assessed are muscle pains, tiredness, etc. The PRS is a 1-10 scale associated with how well you expect to perform on the day based on your perceived recovery. These questionnaires should take less than 5 minutes to fill out each session. These are to filled out prior to every training session.

For each training session, after completing the DALDA and PRS, you will begin with a general warmup and then proceed through the back squat, bench press, and deadlift. You will be allowed to perform 1-2 accessory, non-barbell-based, exercises to supplement your lifting each day.

Each training sessions will last approximately 90-120 minutes.

Upon completion of the 8-week training intervention, you will be asked to perform another assessment of 1RMs on the back squat, bench press, and deadlift and body composition.

Your rights to participate, say no or withdraw:

Participation in research is voluntary. You can decide to participate or not to participate. You can choose to participate in the research study now and then decide to leave the research at any time. Your choice will not be held against you.

The person in charge of the research study can remove you from the research study without your approval. Possible reasons for removal include failing to adhere to the provided training program, failure to complete the daily questionnaires, or multiple missed training sessions.

Potential benefit:

There may be no direct benefit to you from this study. You may obtain personal satisfaction from knowing that you are participating in a project that contributes to new information. Other potential benefits from this study are improved strength, body composition, increased confidence, and self-efficacy.

Potential risks:

The risks associated with this study are minimal in nature. Potential risks include potential muscle soreness and discomfort, decreased confidence, and decreased self-efficacy. There are no foreseen risks to psychological welfare, legal, social, economic or other privacy that you may encounter as part of your participation.

Confidentiality and privacy:

Efforts will be made to limit the use or disclosure of your personal information. This information may include the research study documents or other source documents used for the purpose of conducting the study. We cannot promise complete secrecy. The research team will take steps to ensure all information will remain confidential. Your personal information for this study will be stored within an encrypted USB device. Organizations that oversee research safety may inspect and copy your information. This includes the Seton Hall University Institutional Review Board who oversees the safe and ethical conduct of research at this institution. While the results of the study may be published, your name and personal information will not be made available.

Data sharing and anonymity:

De-identified data from this study may be shared with the research community at large to advance knowledge. We will remove or code any personal information that could identify you before files are shared with other researchers to ensure that, by current scientific standards and known methods, no one will be able to identify you from the information we share. Despite these measures, we cannot guarantee anonymity of your personal data.

Cost and compensation:

You will not be responsible for any of the costs or expenses associated with your participation in this study. There is no payment for your time to participate in this study.

Conflict of interest disclosure:

The principal investigator and members of the study team have no financial conflicts of interest to report.

Contact information:

If you have questions, concerns, or complaints about this research project, you can contact the principal investigator Orlando Rivera at Riveraor@shu.edu, Geneieve Zipp at Genevieve.zipp@shu.edu or the Seton Hall University Institutional Review Board ("IRB") at (973) 761-9334 or irb@shu.edu.

Participation and Consent:

If you wish to participate in this study, please sign below:

I hereby consent to participate in this research study.

Signature of participant	Date
Printed name of participant	
Signature of person obtaining consent	Date
Printed name of person obtaining consent	