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CLINICAL COMMENTARY

CURRENT CONCEPTS IN PERIODIZATION OF STRENGTH AND CONDITIONING FOR THE SPORTS PHYSICAL THERAPIST

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ABSTRACT

The rehabilitation process is driven by the manipulation of training variables that elicit specific adaptations in order to meet established goals. Periodization is an overall concept of training that deals with the division of the training process into specific phases. Programming is the manipulation of the variables within these phases (sets, repetitions, load) that are needed to bring about the specific adaptations desired within that particular period. The current body of literature is very limited when it comes to how these variables are best combined in an injured population since most of the periodization research has been done in a healthy population. This manuscript explores what is currently understood about periodization, gives clinical guidelines for implementation, and provides the sports physical therapist with a framework to apply these principles in designing rehabilitation programs.

Keywords: periodization, sports rehabilitation, strength and conditioning, sports physical therapy, progressive overload, strength, power

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INTRODUCTION

Restoration of strength is arguably the most vital aspect of a rehabilitation plan and is a central tenet of strength and conditioning programs. Strength is the foundation from which all other physical qualities of performance like power, speed, and agility, are developed. Without proper strength development, these qualities cannot be optimized.

Sports physical therapists design programs that include several components including endurance, flexibility, proprioception/kinesthesia, balance, joint and soft tissue mobility, speed, and power.[1] These programs often follow a logical sequence to not only promote optimal healing, but also to restore peak performance. A significant challenge for sports physical therapists is designing optimal training programs that facilitate neural and muscular adaptations while being mindful of biologic healing constraints and safety for the athlete.[1] Unfortunately, most strength training research to date on program design has been conducted on healthy, trained and/or untrained adults,[1-35] while only two studies have been loosely based on rehabilitation.[36,37] Unfortunately, few studies have examined the effect of periodization approaches in adolescent athletic populations.[38]

Periodization is one way for the sports physical therapist to approach the design of resistance training programs. Periodization is defined as the planned manipulation of training variables (load, sets, and repetitions) in order to maximize training adaptations and to prevent the onset of overtraining syndrome.[1,39] It appears from the strength training literature that is available that periodization is usually needed for maximal strength gains to occur,[20,31,30,40-44] although evidence stating otherwise exists.[4,24,45] Periodized training is a safe method of training for older adults, as well as those in pain.[8,46] Periodization has been shown improve training adaptations but the most effective periodization approach for muscular strength development for a wide variety of populations is yet to be determined.[38]

The classic understanding of periodization is attributed to Selye's General Adaptation Syndrome (GAS), the template from which the original concept of periodization was derived.[47] In summary, GAS effectively states that systems will adapt to any stressors they might experience in an attempt to meet the demands of these stressors.[47,48] According to Selye this is accomplished through a process of three phases. Initial reaction to the stressor is termed the *alarm/reaction phase* where the athlete may experience stiffness, soreness, or a small drop in performance from fatigue after the training session. The second phase was termed the *resistance phase* and is where the body responds to the stressor by adapting to the new stress with less soreness, stiffness, more tolerance to activity, and improved performance. This is considered to occur at a level greater than that demanded by the stressor and was termed "*supercompensation*". The final phase occurs if the stressor goes on longer than the organism can adapt, and *exhaustion* results, whereby the athlete may experience staleness in training or deal with symptoms of overtraining.[47] In contrast to Selye, the *fitness-fatigue model* looks at periodization as a balancing act between fitness and fatigue.[49] An individual's level of preparedness is thus a result of the interaction between their level of fitness and the amount of fatigue.[49] This idea has significant implications for programming if preparedness can be optimized by methodical improvements in fitness while minimizing the resulting fatigue.[49] For the neuromuscular system to adapt maximally to the training load or stress, volume and intensity alterations are necessary.[1] Increased demands cause the neuromuscular system to adapt by increasing muscular performance but there is also a concurrent increase in the physical, mental, and metabolic cost of recovery. Without concomitant changes in overload, the system has no need to adapt to stressors. Therefore, no further adaptations are needed and increases in the desired outcome will eventually stop.[20,50] On the other hand, if load is too high, the physiological costs will be too great and the physical readiness for training of the athlete will be comprised. A periodized program helps avoid these issues because the load on the neuromuscular system is varied in order to drive adaptation while minimizing fatigue.

Periodization may also be beneficial due to adding variation to workouts by manipulating sets, repetitions, exercise order, number of exercises, resistance, rest periods, type of contractions, or training frequency.[1,40,48] Another added benefit is the avoidance of training plateaus or boredom.[1,20,50] The reader is referred to Table 1 for a summary of training parameters to address specific training goals.

Table 1. *General Training Guidelines*[102]

Goal	*Rep Range*	*Volume*	*Rest Period*
Power	1-5	Low	Longer
Strength	2-8	Mod	Moderate
Hypertrophy	8-15+	Mod-High	Short-Moderate
Endurance	>15-20	High	Shorter

The purpose of this commentary is threefold. First, a review of various periodization models will be provided, and a discussion about the potential pros and cons of each approach will be explored. A secondary purpose is to provide a sample program or structural framework of the various approaches described herein for the sports physical therapist to implement into a rehabilitation or strength and conditioning program. Finally, a review of programming for maximization of strength and power will be discussed as these two variables are most critical not only for the recovering athlete but also for healthy trained or untrained athletes.

LINEAR PERIODIZATION

The "classic" or "linear" periodization (LP) model is based on changing exercise volume and load across several predictable mesocycles.[1] Classical periodization was originally discussed by Russian scientist Leo Matveyev[51] and further expanded upon by Stone[44] and Bompa.[52] The program is broken down into distinct blocks that are named based on time frames. Planning that spans over a 12-month period is referred to as a *macrocycle*, and two subdivisions are the *mesocycle* (3-4 months) and the *microcycle* (1-4 weeks). Most rehabilitation protocols follow this model. After pain and swelling have subsided, the sports physical therapist typically follows a systematic progression of range of motion, strength, power, and speed with progression to each phase depending on achievement of specific goals in the previous phase. In an athlete recovering from an anterior cruciate ligament (ACL) reconstruction, the mesocycle from months three through six may be strength and power focused, but individual mesocycles may reflect different training loads in one to two weeks of training. There are a number of potential advantages of utilizing a linear approach. First of all, repetition and loading schemes are predictable for both the athlete and the sports physical therapist because they are ultimately determined by what phase the athlete is in. Each phase typically focuses on only one training parameter. Secondly, the linear model helps ensure that each training parameter (strength, power, speed) is addressed in step-wise progression.

Advancement to other training methods is dependent upon successful completion of training in the previous phase. With declining reimbursement as well as allowable visits for physical therapy, another possible advantage of the linear model is that it provides the patient a predictable sequence of loading and repetitions that they can follow when doing supervised independent home exercise programs. Effectively, the linear program helps take the "guesswork" out of loading and repetitions schemes.

There are also several potential disadvantages to the linear program. The linear program was originally devised as a training model for preparing for one peak competition per year in Olympic weightlifters.[51] For athletes that play several sports or athletes that have multiple competitions in a season, this may not be optimal as an athlete's tolerance to loading may ebb and flow based on injuries or frequency/intensity of competition. Another potential disadvantage is that maintenance of specific training parameters is difficult once an athlete transitions to another phase. For example, an athlete may have a six-week strength phase, but once they transition to the power phase, there may be a decline in strength since the loading and repetition schemes for the power phase are not well-aligned with strength development. Unfortunately, all of these potential advantages and disadvantages are speculative at this time. The reader is referred to Table 2 for a one-week sample program of lower extremity strengthening utilizing linear periodization.

Author's note: For all sample programs, 2-3 "core" lifts (total body lifts i.e. squat, deadlift, and power clean central to athletic development) will be used to illustrate how program design would occur. Such sample programs are not meant to be all-inclusive and could include many other exercises (i.e lunges, step ups, calf raises) that may be added in order to provide a comprehensive program for the athlete.

Table 2. *Linear Periodization*

Exercise	Set/rep	Intensity
Hypertrophy/Endurance		*Zone 2*
Hang Clean	4x6	55% 1RM
Back Squat	3x12	70% 1 RM
Single Leg Deadlift	3x12	70% 1RM
Strength		*Zone 3*
Power Clean	4x3	85% 1RM
Front Squat	4x6	80% 1RM
Single Leg Deadlift	4x6	80% 1RM
Max Strength/Power		*Zone 4*
Hang Power Clean	6x1	90% 1RM
Front Squat	3x3	90% 1RM
Trap Bar Deadlift	3x5	85% 1RM

NON-LINEAR/UNDULATING

The other main model is the non-linear or "undulating" periodization model, first proposed by Poliquin.[53] While undulating periodization has been used, the term "non-linear" has become more favorable. Non-linear periodization (NP) is based on the concept that volume and load are altered more frequently (daily, weekly, biweekly) in order to allow the neuromuscular system longer periods of recovery as lighter loads are performed more often.[1] In the NP model, there are more frequent changes in stimuli. These more frequent changes may be highly conducive to strength gains.[1,53]

There are many potential advantages to the NP approach, although no definitive conclusions can be made at this time. First of all, the weekly fluctuations in training loads may lead to better neuromuscular adaptations compared to the LP approach, as loads are more unpredictable. Secondly, the NP program accounts for the need for modifications in the training program based on an athlete's recovery from competition or from a previous workout/training session. Additionally, in the NP model, several training parameters may be addressed at the same time. Therefore, an athlete may address power and strength within the same week. Finally, due to the concurrent nature of the training, the detraining effects that occur in a LP approach might be avoided.

Like LP, there are a few potential disadvantages for the NP approach. Particularly in the recovering athlete, the athlete may not be appropriate for lifts focusing on power development, like the clean and snatch, if an appropriate strength base has yet to be achieved or established. Therefore, a "power" session may not be indicated. Finally, the NP program may not allow each performance characteristic to be optimally developed due to focus on several parameters at once. Again, definitive conclusions cannot be made at this time about the advantages or disadvantages to the NP approach.

The reader is referred to Table 3 for a one-week sample program of NP.

Evidence-Based Update: LP vs. NP

A recent meta-analysis and systematic review by Harries et al found that were no differences in the effectiveness of linear vs. undulating periodization on upper-body or lower-body strength in healthy trained and untrained subjects.[38] Possible explanations include the short-term nature of studies and the previous training history of participants. The results sug-

Table 3. *Non-Linear Periodization*

Exercise	Sets/reps	Intensity
Workout 1		*Zone 3*
Hang Clean	3x3	80% 1RM
Back Squat	4x5	80% 1RM
Workout 2		*Zone 1/2*
Hang Snatch	3x5	50% 1RM
Front Squat	3x12	50% 1RM
Leg Press	3x12	50% 1RM
Workout 3		*Zone 2*
Deadlift	3x8	70% 1RM
Back Squat	3x8	70% 1RM
Leg Press	3x8	70% 1RM

RM= repetition maximum

gest that novelty or training variety are important for stimulating further strength development.[38] Based on available data, it appears that daily program manipulation is more beneficial than non-periodized training for eliciting strength gains.[9]

To date, most authors have found only minimal differences in strength and power measures between LP and NP.[1] Recent studies by Franchini et al[54] in judo athletes, Miranda et al[55] in resistance trained men training with the leg press and bench press, de Lima et al[56] in young, sedentary women, Prestes et al[19] in previously trained females, Baker[3] and Buford et al[39] in trained males, Rhea et al[20] and Rhea et al[21] in untrained men and women, and Hoffman et al[9] in American football players determined that neither LP or NP were superior. Although there were subtle differences in outcome measures studied, but these differences were not statistically significant. No definitive conclusions can be made at this time as to which method is preferred.

BLOCK PERIODIZATION

Block periodization is an approach to the periodization of strength that has experienced a renewed interest of late.[57] Block periodization involves highly concentrated, specialized workloads. Each step in the training cycle has a large volume of exercises focused on specific, targeted training abilities to ensure maximum adaptation. The rationale for block periodization is that traditional models often account for only one "peak" per year, while many athletes have numerous competitions throughout the year (basketball, soccer, baseball, etc). The LP model increases basic qualities, but these tend to decline during the competitive season. The block system allows for these qualities to be maintained throughout the year. This is known as the *long-lasting delayed training effect* – retention of changes even after the cessation of training.[58] Issurin has proposed that power and strength can be maintained for up to 30 days while peak performance can be maintained for 5-8 days.[57,58] Furthermore, the "classic" models, like LP and NP, have time devoted to endurance, strength, power, and speed, regardless of the sport. In the block approach, if an athlete doesn't require endurance for their sport, it is not a focus of training. Similarly, the block approach would not include balance, strength, and agility in one training block – they would be performed separately with a specific focus. Another example of differences in the block approach is the concept of "complex training," whereby a strength exercise is followed by a biomechanically similar plyometric exercise (i.e. back squat followed by a squat jump). Because these exercises comprise two different training modalities (strength and power), they would not be performed simultaneously. On the contrary, complex training would be used in an LP or NP programs. Another difference is that the block program is broken down into 2-4 week blocks, while the linear and non-linear models have at least four-week phases. In other words, an athlete may do strength, power, and peaking within four weeks while it may be several months before each phase is completed in the LP or NP because they are of longer duration.

The block approach is divided into three distinct phases.[58] The *accumulation phase* builds work capacity. Compared to the other two phases, there is a higher volume of exercises performed at 50-70% of 1RM, composed of general movements. Typically, this phase may last from 2-6 weeks, based on how long the athlete has till the competitive season, as well as their training history. Untrained athletes would require more time in this phase. The second phase is the *transmutation phase*. In this phase, specific exercises with greater loads, comprising 75-90% of 1RM are performed. Accommodating resistance, like the use of chains or elastic bands with squats, may be used to promote a strength overload. Finally, the *realization phase* is comprised of even more specific movements than the transmutation phase with loads at 90% of 1RM or greater. For example, accommodating resistance in not typically used in this phase. Instead, athletes will perform >90% 1RM squats, deadlift, bench press, cleans, etc. In some cases, there is a week of reduced loading and volume following the realization phase to allow recovery due to the high-intensities utilized within the realization phase.

Evidence-Based Update: Block Periodization

There are a few studies that have utilized the block approach compared to other approaches. To the authors' knowledge, only one study by Bartolomei et al[59] did not support the block model when compared to an NP program with regard to strength, power, and hypertrophy in recreationally-trained women. Another study by Bartolomei et al[60] found there were no differences between the block and a more traditional LP program on upper and lower body strength in trained athletes. Compared to the LP approach block training was found to be a superior method of training by Ronnstad et al[61] in a group of cyclists for VO2max and power output, Ronnstad and others[62] in a group of elite cross country skiers for peak power and maximal oxygen uptake, and by Breil and coauthors[63] in elite junior alpine skiers. Interestingly, two studies found that the block program lead to greater improvements in strength per volume of load when compared to other programs.[60,64] In other words, the block program was more efficient in training effectiveness.

In summary, block periodization is showing some promise when compared to more common approaches like LP and NP. The positive results may be partially explained by the fact that the block periodization studies were short in duration and the intensity was high. The intensity seemed to be a direct correlate to performance. Furthermore, it appears that the block program was indeed better for athletes who have multiple events per year (cycling, skiing, track, etc). More research is needed before definitive conclusions can be made. See Table 4 for a generalized four-week block program and Table 5 for more specific training parameters (sets, repetitions, load).

Programming for Strength and Conditioning

The periodization schemes laid out previously define methods of sequencing the training process over time. In turn, the creation of the specific program within the selected periodization scheme drives the desired adaptations. This process is built around the principles of overload, variation, and specificity. *Overload* is described as a stimulus of sufficient strength, duration, and frequency as such that it forces an organism to adapt.[65] *Variation* describes the manipulation of training variables that changes the overload stimulus. These variables are traditionally considered to be the exercise type, the order performed, the intensity (percentage of repetition maximum) prescribed, as well as the sets, repetitions and rest periods assigned. *Specificity* can be approached via a bioenergetics or metabolic and/or mechanical perspective. Siff and Verkoshansky laid out a number of considerations for addressing mechanical specificity such as looking at the movement's amplitude and direction, the dynamics of the effort, the rates of force development, and contraction types.[66]

When viewed from a bioenergetics perspective, a task analysis must be performed and the identified demands on the energy systems should be reflected in the programming. A growing body of literature exists specific to the energy system demands of sport. For example, researchers have found that the physiologic demands in American football include 7-10 seconds of maximal effort followed by 20-60 seconds of recovery.[8] When specific research is unavail-

Table 4. *Block Periodization - General Structure*

Week 1	*Sets/reps*	*Intensity*
Push Press	3x10	50% 1RM
Back/Front Squats	3x12	50% 1RM
Leg Press/Hack Squat	3x12	50% 1RM
Step Ups	2x12	
Lunges	2x8 ea	
Week 2		
Push Press	3x8	60% 1RM
Back/Front Squats	3x10	60% 1RM
Leg Press/Hack Squat	3x10	60% 1RM
Trap Bar Deadlift	3x8	60% 1RM
***Week 3-4: Transmutation Phase*. Increased loading**		
Week 3	*Sets/reps*	*Intensity*
Hang Clean/Hang Snatch	3x4	75% 1RM
Back/Front Squat	3x6	80% 1RM
Deadlift/Trap Bar Deadlift	3x6	80% 1RM
Week 4		
Hang Clean	4x3	85% 1RM
Back/Front Squats with accommodating resistance	4x6	75% 1RM with bands
Week 5: Realization Phase. Peak power. Intensity can be based on sport demands		
Hang Clean	4x2	90% 1RM
Squats (Front or Back)	4x5	90% 1RM – complete as fast as possible
Alternative Lifts: Deadlifts, Hang Snatch		
***Week 6: Restoration Phase*. Reduced loading to follow high intensity work**		
Choose several exercises <50% 1RM. Emphasize total body workouts with light loads and high repetitions.		
After this 6-week block, the athlete repeats each phase.		
RM= repetition maximum		

Table 5. *Block Periodization – Detailed Description*

Phase	Objectives	Example Exercise Sequence	Intensities	Sets x Reps	Duration
General Capacity/Tissue Healing	Build work capacity & general fitness. Promote Healing.	6-8 exercises selected based on ability to perform w/o damage to healing tissue but still impose metabolic load	Zone 1 or lower end of 2 at 6-7 RPE	2-3 sets x 10-15 reps; Rest ~2 min between circuits	2-4 weeks
Accumulation	Continue to build work capacity with more specific emphasis (Hypertrophy is a potential goal)	2-3 core lifts with 3-5 accessory lifts	Zone 2 strength; Zone 1 power	Core exercises 8-12 reps for 25-35 total reps	3-4 weeks
Transmutation	Focus on specific emphasis with specialized work to address main limitations. Maintain aerobic base.	1-2 main lifts, 1-2 specialized lifts and 3-4 accessory lifts; Cardiac work 2-3 days/week	Zone 3 strength; Zone 2/3 power	4-6 reps per set for 12-24 total reps	2-4 weeks
Realization	Bring everything together and emphasize power and max strength work.	1 main exercise each day; 1-2 accessory exercise; maintain Cardiac Workouts	Zone 4 strength and power work	1-4 reps per set for 8-15 total reps	2 weeks
Restoration	Choose several exercises <50% 1RM. Emphasize total body workouts with light loads and high repetitions.				

able to describe physiologic demands of a sport, a demands analysis must be performed in order to determine the specific needs of the athlete. The rehabilitation programming should be structured to prepare the athlete for the metabolic demands of their specific sport.

Load

Without monitoring and adaptation the most elegant program can quickly become irrelevant. Furthermore, the sports physical therapist has the added challenge of dealing with the healing process. While adherence to a consistent approach will drive adaptation, structured variability is also necessary within this framework to ensure relevance on any given day. Because of this, a method of programming that is modifiable based on relevant feedback is important. One such method is autoregulation, a modification of the daily adjusted progressive resistive exercise (DAPRE) system that allows for a more flexible application than more traditional approaches.[68,69] This modified protocol is a zone-based approach built around a focus on strength/power, strength/hypertrophy, and hypertrophy (Table 6). This approach has been applied successfully in both rehabilitation and performance based settings and has been shown to actually outperform more standard methods of periodization in some cases.[70] The use of Rating of Perceived Exertion (RPE) has been shown to be a reliable measure of session intensity as well as specific exercise intensity within a training session.[71-73] The use of RPE offers a significant

Table 6. *Daily Adjusted Progressive Resistance/Autoregulatory*[68,69,70]

Zones	**Goal**	**Rep Range**	**Sets**	**Load**
Zone 1	Strength/Power	3RM	Warmup	<50% of RM
Zone 2	Strength/Hypertrophy	6RM	1	50% of RM
Zone 3	Hypertrophy	10RM	2	75% of RM
Final Set Adjustment			3	Reps to failure at RM
4+ reps below RM/RPE, reduce load 2.5-5kg				
2-3 reps below RM/RPE, reduce load by 0-2.5kg			4	Adjusted reps to failure based on final set adjustment
1 rep above/below or RM/RPE goal, keep the same load				
2-3 reps above RM/RPE, add 2.5-5kg				
4+ reps above RM/RPE, add 5-7.5kg				

RM= repetition maximum   RPE= rating of perceived exertion

advantage for the rehabilitation professional since it allows for monitoring intensity without establishing a true one-repetition maximum (1RM), which is often contraindicated due to stages of healing. Other models exist to estimate 1RM without actually lifting a true 1RM such as the Oddvar Holten Curve[74] and other models by Baechle et al which are used to establish an estimated 1RM based off of submaximal loads taken to failure.[75]

Velocity based training is another within-session method of monitoring that has grown increasingly popular as the technology for monitoring repetition velocity in the clinic or gym has become available. Research at this point is still emerging but a few practical models have been developed that determine intensity based on the velocity of the bar during the lift and the end of the set being based on a predetermined decrease in velocity.[76] When applied systematically this approach allows for immediate feedback, fatigue control, prediction and monitoring of biomotor changes, and a guide to the training process.[77] To the authors' knowledge, velocity-based training has not been studied in rehabilitative literature to date.

Strength

Strength should be considered fundamental to all other aspects of training and forms the foundation of most successful return to play (RTP) approaches.[78] Strength is defined as the ability to produce force[68] and is traditionally measured with a single repetition maximum (RM) or by taking a percentage of RM to failure with the RM calculated based on a percentage table. Strength is closely correlated with the capacity to rapidly produce high levels of force and as a result maximal force development should be the initial emphasis with those presenting with lower levels of strength.[79-81] The mechanism proposed for this increase in force as a result of strength work has been attributed to increased muscle cross-sectional area and changes in neural drive.[79] Exercise intensity or load is commonly accepted as one of the critical components for achieving strength based adaptations. This is fairly well supported in the literature and the common recommendation of loads approximately >80% of RM in trained individuals should build the foundation of most programming for strength.[50,82,83]

Optimal dosage has been debated, but the evidence to date supports multiple sets over single sets with up to 46% greater strength gains and 40% increase in hypertrophy seen when comparing multiple set to single set approaches in trained and untrained healthy individuals.[50,82-85] Peterson also found that three to four sets per exercise with approximately eight sets per muscle group elicited the greatest pre/

post effect sizes (standardized mean differences) in strength.[84] When multiple sets are not an option, single set training taken to failure is still of a sufficient stimulus to elicit significant changes in strength and hypertrophy.[50,82-86]

This brief review of strength principles highlighted some of the considerations that the sports rehabilitation professional must consider when programming within any of the periodization schemes. Practical recommendations for strength training loads are presented in Table 7**.**

Power

Many aspects of sport and daily life require the ability to produce relatively high levels of force in a brief period of time. This characteristic is commonly described as power although there are some concerns that this term may not be as accurate as the biomechanical term, impulse.[87] For the purpose of this paper the term will be used in its commonly accepted definition. Power is defined as the rate at which work is performed and is the product of force and velocity. As a result it becomes apparent that the ability to apply high levels of force in a brief period of time and to contract at high velocities are vital components of its development.[88] The importance of power development in the rehabilitation environment ranges from fall risk reduction in the elderly[89,90] to returning an athlete to sport post anterior cruciate ligament reconstruction.[91] In athletics the ability to produce high power outputs with a high rate of force development has been proposed by Stone et al to be a critical aspect of success in many sports.[92] As such an understanding of power development and its integration into a periodization approach is important.

Table 7. *Intensity Training Zones[104] *All loads expressed as percentage of 1RM*

	Strength	Power
Zone 1	General muscle and technical <50%	General neural and technical <25%
Zone 2	Hypertrophy training 50-75%	Ballistic speed training 25-37.5%
Zone 3	Basic strength training 75-90%	Basic power training 37.5-45%
Zone 4	Maximal strength training 90-100%	Maximal power training 45-55%

RM= repetition maximum

Power development can be subdivided into a focus on muscular strength, rate of force development, and maximal force at high velocities of movement.[81] There are excellent arguments for a high load approach (50-70% of one repetition maximum 1RM) as well as for a low load approach (<50% [1RM]) in exclusion but a "mixed methods approach" combining both appears to be the most beneficial.[93,94] This approach to training for power has been suggested as optimal since it combines heavy resistance training with higher velocity work in order to develop power production across the entire force/velocity spectrum.[80.81] The result is more relevant adaptations when compared with strength training or ballistic exercise alone. For the novice trainee, focused strength development alone is often sufficient for power development without the addition of any specific work[80,81,95] and in general, a stronger individual responds better to the addition of specific power-based exercises than a weaker counterpart.[79] It should be noted that all guidelines are general and acceptable levels of strength prior to initiation of power work is dependent on the individual and the demands of their task. Regardless of the specifics, maximal strength levels constrain the upper limits of maximal power output. The ability to generate force rapidly is of little use if the level of force generated is below a necessary threshold and thus adequate strength levels form the foundation of maximal neuromuscular power development.[32,80]

Cormie et al randomized individuals into groups based on their squat 1RM to body mass ratio.[79] They found that the stronger individuals displayed greater power production initially and also a trend towards a greater effect size when compared to the weaker group although both groups improved at a similar magnitude and displayed similar adaptive abilities when exposed to lower extremity ballistic (plyometric) power training. As a result, the authors concluded that there is potential benefit to developing strength initially before performing a focused ballistic program. In addition, they advise regarding the importance of maintaining strength throughout a power-specific training phase since decreases in maximal strength are theorized to result in a decreased ability to adapt to ballistic training.

There is a paucity of data with regard to power development or training in the upper body, but the same trend for stronger athletes to respond better to ballistic work compared to their weaker counterparts has also been seen. Young et al[100] found that athletes with a lower bench press repetition maximum benefited more from strength work, however, those with higher relative strength also benefit from the inclusion of ballistic work. Mangine et al[96] took a group of 17 resistance-trained men and compared combined ballistic and heavy resistance work with a group that only performed heavy resistance training. Their findings indicated that the addition of ballistic exercise increased power when compared to strength training alone.

Training for Power

Ballistic training, which includes techniques such as jump squats, medicine ball throws, and box jumps has been argued to impact the high velocity area of the force velocity curve. This is in contrast to power work done with heavier loads, such as the Olympic lifts, which will have a greater effect on the higher force aspect of this relationship. These exercises also differ from more traditional strength exercises in that they allow for acceleration throughout the entire movement, versus something like the bench press where up to 52% of the exercise duration is deceleration.[80.81]

The concept of optimal load training indicates that training loads should be chosen to allow for maximal power output as this is the most effective means of further power development.[97,98] Neglecting higher load work can be problematic however since training power at higher loads results in higher power outputs at heavier loads which is very important in sports such as American football or rugby.[99] Optimal power development across the entire force velocity profile therefore requires training across the full spectrum of loads and velocities. While training with the intent to move explosively is very important a majority of the research demonstrates velocity-specific adaptations to training.[80] Thus, all exercises should be performed as rapidly as possible regardless of the actual speed of exercise. Table 8 gives some general recommendations for power training intensity zones based on various exercises commonly used for power development.

Conclusions and Directions for Future Research

At this time, the research on periodization is limited, not only in the rehabilitation literature but also in strength and conditioning. The block model has not yet been studied in rehabilitation literature. Further, previous papers have shown that there is clear benefit to periodization over non-periodized programs, but there is no conclusive evidence that LP or NP is superior to the other.[1] Likewise, block periodization has not been established as the definitive approach, but early studies show some promise with training improvements. Clearly, there is potential to use these various models for more "long term" rehabilitation programs, such as labral repairs of the hip and shoulder, rotator cuff repairs, ulnar collateral ligament reconstructions, or anterior cruciate ligament reconstructions, to see if recovery time can be improved or clinical testing methods for performance can be optimized. Additionally, use of these periodization models has not been utilized in interval sport programs. Truly, this is a relatively unexplored area of

Table 8. *Optimal Power Load*

Exercise	*Optimal Power Load (Range)*
Jump Squat[97,105,106]	0% of 1RM
Power Clean[103,105,106]	80% of 1RM (50-90%)
Squat[105,106]	56% of 1RM (42-71%)
Bench Press Throw[3,80,94,104]	30-45% of 1RM (46-62% in highly trained athletes)

RM= repetition maximum

research and there are vast opportunities for studies to be conducted, all with the goal of maximizing long-term athletic rehabilitation, development, and performance.

REFERENCES

1. Lorenz DS, Reiman MP, Walker JC. Periodization: Current review and suggested implementation for athletic rehabilitation. *Sports Health*. 2010;2(6):509-518.
2. Anderson T, Kearney JT. Effects of three resistance training programs on muscular strength and absolute and relative endurance. *Res Q*. 1982;53:1–7.
3. Baker D: A series of studies on the training of high-intensity muscle power and rugby league football player. *J Strength Conditioning Res.* 2001;15:198-209.
4. Baker D, Wilson G, Carolyn R. Periodization: The effect on strength of manipulating volume and intensity. *J Strength Cond Res*. 1994; 8: 235-242.
5. Berger RA. Effect of varied weight training programs on strength. *Res Q*. 1962;33:168–181.
6. Borst SE, Dehoyos DV, Garzarella L, et al. Effects of resistance training on insulin-like growth factor-1 and IGF binding proteins. *Med Sci Sports Exerc*. 2001;33:648–653.
7. Capen EK. Study of four programs of heavy resistance exercises for development of muscular strength. *Res Q*. 1956;27:132–142.
8. Häkkinen K, Alen M, Komi PV. Changes in isometric force-and relaxation-time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. *Acta Physiol Scand*. 1985;125:573–585.
9. Hoffman J, Ratamess N, Klatt M, et al. Comparison between different off-season resistance training programs in Division III American college football players. *J Strength Cond Res*. 2009; 23; 11-19.
10. Jacobson BH. A comparison of two progressive weight training techniques on knee extensor strength. *J Athl Train*. 1986;21:315–319.
11. Kemmler WK, Lauber D, Engelke K, Weineck J. Effects of single- vs. multiple-set resistance training on maximum strength and body composition in trained postmenopausal women. *J Strength Cond Res*. 2004;18:689–694.
12. Kraemer WJ. A series of studies-the physiological basis for strength training in American football: fact over philosophy. *J Strength Cond Res*. 1997;11:131–142.
13. Kraemer WJ, Ratamess N, Fry AC, et al. Influence of resistance training volume and periodization on physiological and performance adaptations in college women tennis players. *Am J Sports Med*. 2000;28:626–633.
14. Kraemer, WJ, et al. Physiological changes with periodized resistance training in women tennis players. *Med Sci Sports Exerc* 35: 157-168, 2003.
15. Kraemer WJ, SJ Fleck. Optimizing strength training: designing non-linear periodization workouts. Champaign, IL: Human Kinetics, 2007.
16. Mayhew JL, Gross PM. Body composition changes in young women with high resistance training. *Res Q*. 1974;45:433–440.
17. Newton RU, Kraemer WJ, Hakkinen K: Effects of ballistic training on preseason preparation of elite volleyball players. *Med Sci Sports Exerc.* 1999;31:323-330.
18. Ohberg L, R Lorentzon, and H Alfredson. Eccentric training in patients with chronic Achilles tendinosis: normalized tendon structure and decreased thickness at follow-up. *Br J Sports Med* 2004; 38:8-11.
19. Prestes J, De Lima C, Frollini AB, et al. Comparison of linear and reverse linear periodization effects on maximal strength and body composition. *J Strength Cond Res*. 2009; 23: 266-274.
20. Rhea MR, Ball SD, Phillips WT, Burkett LN. A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *J Strength Cond Res.* 2002; 16(2): 250-255.
21. Rhea MR, Phillips WT, Burkett LN, et al. A comparison of linear and daily undulating programs with equated volume and intensity for local muscular endurance. *J Strength Cond Res*. 2003; 17: 82-87.
22. Rhea MR, Alvar BA, Ball SD, Burkett LN. Three sets of weight training superior to 1 set with equal intensity for eliciting strength. *J Strength Cond Res*. 2002;16:525–529.
23. Sanborn K, Boros R, Hruby J, et al. Short-term performance effects of weight training with multiple sets not to failure vs a single set to failure in women. *J Strength Cond Res*. 2000;14:328–331.
24. Schiotz MK, Potteiger JA, Huntsinger PG, Denmark DC. The short-term effects of periodized and constant-intensity training on body composition, strength, and performance. *J Strength Cond Res*. 1998; 12: 173-178.
25. Schlumberger A, Stec J, Schmidtbleicher D. Single- vs. multiple-set strength training in women. *J Strength Cond Res*. 2001;15:284–289.
26. Starkey DB, Pollock ML, Ishida Y, et al. Effect of resistance training volume on strength and muscle thickness. *Med Sci Sports Exerc*. 1996;28:1311–1320.

27. Stone MH, Johnson RL, Carter DR. A short term comparison of two different methods of resistance training on leg strength and power. *J Athl Train*. 1979;14:158–161.
28. Stone WJ, Coulter SP. Strength/endurance effects from three resistance training protocols with women. *J Strength Cond Res*. 1994;8:231–234.
29. Stowers T, McMillian J, Scala D, et al. The short-term effects of three different strength-power training methods. *NSCA J*. 1983;5:24–27.
30. Weiss LW, Coney HD, Clark FC. Differential functional adaptations to short-term low-, moderate and high-repetition weight training. *J Strength Cond Res*. 1999;13:236-241.
31. Willoughby DS. The effects of mesocycle-length weight training programs involving periodization and partially equated volumes on upper and lower body strength. *J Strength Cond Res*. 1993; 7: 2-8.
32. Wilson GJ, Murphy AJ, Walshe AD: Performance benefits from weight and plyometric training: effects of initial strength levels. *Coach Sport Sci J.* 1997;2:3-8.
33. Wilson GJ, Newton RU, Murphy AJ, et al: The optimal training load for the development of dynamic athletic performance. *Med Sci Sports Exerc.* 1993;25(11):1279-1286.
34. Witvrouw E, Danneels L, Van Tiggelen D, et al. Open versus closed kinetic chain exercises in patellofemoral pain: a five year prospective randomized study. *Am J Sports Med.* 2004; 32: 1122-1130.
35. Zaryski C, Smith DJ. Training principles and issues for ultra-endurance athletes. *Curr Sports Med Rep*. 2005; 4(3): 165-170.
36. Kell R, Asmundson G. A comparison of two forms of periodized exercise rehabilitation programs in the management of chronic nonspecific low-back pain. *J Strength Cond Res*. 2009; 23; 513-523.
37. Wong Y, Chan S, Tang K, Ng G. Two modes of weight training programs and patellar stabilization. *J Ath Train*. 2009; 44(3): 264-271.
38. Harries SK, Lubans DR, Callister R. Systematic review and meta-analysis of linear and undulating periodized resistance training programs on muscular strength. *J Strength Cond Res*. 2015; 29(4): 1113-1125.
39. Buford TW, Rossi SJ, Smith DB, Warren AJ. A comparison of periodization models during nine weeks with equated volume and intensity for strength. *J Strength Cond Res*. 2007; 21(4): 1245-1250.
40. Fleck SJ, Kraemer WJ: *Designing Resistance Training Programs,* ed 3, Champaign, IL, 2004, Human Kinetics.
41. Fleck SJ. Periodized strength training: a critical review. *J Strength Cond Res*. 1999; 13: 82-89.
42. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc*. 2004; 36: 697-688.
43. Pearson D, Faigenbaum A, Conley M, Kraemer WJ. The National Strength and Conditioning Association's basic guidelines for the resistance training of athletes. *Strength Cond J*. 2000; 22: 14-27.
44. Stone MH, O'Bryant HS. *Weight Training: A Scientific Approach*. Minneapolis: Burgess. 1987.
45. Alfredson H, Pietila T, Jonsson P, Lorenzton R. Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med*. 1998; 26: 360-366.
46. Kell R, Asmundson G. A comparison of two forms of periodized exercise rehabilitation programs in the management of chronic nonspecific low-back pain. *J Strength Cond Res*. 2009; 23; 513-523.
47. Selye H. *Stress without distress*. New York: J.B. Lippincott, 1974.
48. Rhea MR, Alderman BL. A meta-analysis of periodized versus nonperiodized strength and power training programs. *Res Q Exerc Sport*. 2004; 75: 413-423.
49. Plisk SS, Stone MH. Periodization strategies. *Strength Cond J*. 2003; 25(6): 19-37.
50. Rhea MR, Alvar BA, Burkett LN, Ball SD. A meta-analysis to determine the dose response for strength development. *Med Sci Sports Exerc*. 2003;35:456–464.
51. Matveyev L. Fundamentals of Sports Training. Moscow: Progress, 1981.
52. Bompa TO. *Theory and Methodology of Training: The key to athletic performance*. Dubuque, IA: Kendall/Hunt, 1994.
53. Poliquin C. Five steps to increasing the effectiveness of your strength training program. *NSCA J*. 1988; 10: 34-39.
54. Franchini E, Branco BM, Agostino MF, et al. Influence of linear and undulating strength periodization on physical fitness, physiological, and performance responses to simulated judo matches. *J Strength Cond Res*. 29(2): 358-367.
55. Miranda F, Simao R, Rhea M, et al. Effects of linear vs. daily undulatory periodized resistance training on maximal and submaximal strength gains. *J Strength Cond Res*. 2011; 25(7): 1824-1830.
56. de Lima C, Boulossa DA, Frolini AB, et al. Linear and daily undulating resistance training periodizations have differential beneficial effects in young sedentary women. *Int J Sports Med.* 2012; 33(9): 723-727.
57. Issurin VB. New horizons for the methodology and physiology of training periodization. *Sports Med*. 2010; 40(3); 189-206.

58. Dietz C, Peterson B. Triphasic Training: A Systematic Approach to Elite Speed and Explosive Strength Performance. Hudson, WI: Bye Dietz Sport Enterprise.
59. Bartolomei S, Stout JR, Fukuda DH, et al. Block versus weekly undulating periodized resistance training programs in women. *J Strength Cond Res*. 2015. Epub ahead of print.
60. Bartolomei S, Hoffman JR, Memi F, Stout JR. A comparison of traditional and block periodized strength training programs in trained athletes. *J Strength Cond Res*. 2014; 28(4): 990-997.
61. Ronnstad BR, Hansen J, Ellefsen S. Block periodization of high-intensity aerobic intervals provides superior training effects in trained cyclists. *Scan J Med Sci Sports*. 2014; 24(1): 34-42.
62. Ronnstad BR, Hansen J, Thyli V, et al. 5-week block periodization increases aerobic power in elite cross-country skiers. *Scand J Med Sci Sports*. 2015; Feb 3. Epub ahead of print.
63. Breil FA, Weber SN, Koller S, et al. Block training periodization in alpine skiing: effects of 11-day HIT on VO2max and performance. *Eur J Appl Physiol*. 2010; 109(6): 1077-1086.
64. Painter KB, Haff GG, Ramsey MW, et al. Strength gains: block versus daily undulating periodization weight training among track and field athletes. *Int J Physiol Perform*. 2012; 7(2): 161-169.
65. Cardinale M, Newton R, Nosaka K. *Strength and Conditioning*. Wiley; 2011.
66. Verkhoshansky YV, Siff MC. *Supertraining*. Verkhoshansky.com; 2009.
67. Iosia MF, Bishop PA. Analysis of exercise-to-rest ratios during division IA televised football competition. *J Strength Cond Res*. 2008;22(2):332-340.
68. Rhea MR, Hunter RL, Hunter TJ. Competition modeling of American football: observational data and implications for high school, collegiate, and professional player conditioning. *Journal of Strength and Conditioning Research*. 2006;20(1):58-61.
68. Siff MC, Verkoshansky YV. Supertraining. Denver, CO: Supertraining International, 4th ed. 1999.
69. Knight KL. Knee rehabilitation by the daily adjustable progressive resistive exercise technique. *Am J Sports Med*. 1979;7(6):336-337.
70. Mann JB, Thyfault JP, Ivey PA, et al. The effect of autoregulatory progressive resistance exercise vs. linear periodization on strength improvement in college athletes. *J Strength Cond Res*. 2010;24(7):1718-1723.
71. Day ML, McGuigan MR, Brice G, et al. Monitoring exercise intensity during resistance training using the session RPE scale. *Journal of Strength and Conditioning Research*. 2004;18(2):353-358.
72. Kraft JA, Green JM, Gast TM. Work Distribution Influences Session Ratings of Perceived Exertion Response During Resistance Exercise Matched for Total Volume. *Journal of Strength and Conditioning Research*. 2014;28(7):2042-2046.
73. Lins-Filho O de L, Robertson RJ, Farah BQ, et al. Effects of exercise intensity on rating of perceived exertion during a multiple-set resistance exercise session. *J Strength Cond Res*. 2012;26(2):466-472.
74. Holten Institute. www.holteninstitute.com. Downloaded 5/29/2015.
75. Baechle TR, Earle RW, Wathen D. Resistance training. In: Baechle TR, Earle RW, eds. Essentials of Strength Training and Conditioning. 2nd ed. Champaign, IL: Human Kinetics, 395-425. 2000.
76. González-Badillo JJ, Marques MC, Sánchez-Medina L. The importance of movement velocity as a measure to control resistance training intensity. *J Hum Kinet*. 2011;29A(Special Issue):15-19.
77. Jovanovic M, Flanagan EP. Researched applications of velocity based strength training. 22(2)58-69. 2014. *J Aust Strength Cond*. 2014;22(2):58-69.
78. Petersen W, Taheri P, Forkel P, et al. Return to play following ACL reconstruction: a systematic review about strength deficits. *Arch Orthop Trauma Surg*. 2014;134(10):1417-1428.
79. Cormie P, McGuigan MR, Newton RU. Influence of strength on magnitude and mechanisms of adaptation to power training. *Med Sci Sports Exerc*. 2010;42(8):1566-1581.
80. Cormie P, McGuigan MR, Newton RU. Developing maximal neuromuscular power. *Sports Med*. 2011;41(1):17-38.
81. Haff GG, Nimphius S. Training Principles for Power. *Strength & Conditioning Journal*. 2012.
82. Peterson MD, Rhea MR, Alvar BA. Applications of the dose-response for muscular strength development: a review of meta-analytic efficacy and reliability for designing training prescription. *J Strength Cond Res*. 2005;19(4):950-958.
83. Peterson MD, Rhea MR, Alvar BA. Maximizing strength development in athletes: a meta-analysis to determine the dose-response relationship. *Journal of Strength and Conditioning Research*. 2004;18(2):377-382.
84. Krieger JW. Single vs. multiple sets of resistance exercise for muscle hypertrophy: a meta-analysis. *J Strength Cond Res*. 2010;24(4):1150-1159.
85. Krieger JW. Single versus multiple sets of resistance exercise: a meta-regression. *J Strength Cond Res*. 2009;23(6):1890-1901.

86. Fisher J, Steele J, Bruce-Low S, Smith D. Evidence-based resistance training recommendations. *Med Sport*. 2011.
87. Knudson DV. Correcting the use of the term "power" in the strength and conditioning literature. *J Strength Cond Res*. 2009;23(6):1902-1908.
88. Kawamori N, Haff GG. The optimal training load for the development of muscular power. *Journal of Strength and Conditioning Research*. 2004;18(3):675-684.
89. Orr R, Raymond J, Fiatarone Singh M. Efficacy of progressive resistance training on balance performance in older adults : a systematic review of randomized controlled trials. *Sports Med*. 2008;38(4):317-343.
90. Granacher U, Zahner L, Gollhofer A. Strength, power, and postural control in seniors: Considerations for functional adaptations and for fall prevention. *European Journal of Sport Science*. 2008;8(6):325-340.
91. Angelozzi M, Madama M, Corsica C, et al. Rate of force development as an adjunctive outcome measure for return-to-sport decisions after anterior cruciate ligament reconstruction. *The Journal of orthopaedic and sports physical therapy*. 2012;42(9):772-780.
92. Stone MH, Moir G, Glaister M, et al. How much strength is necessary? *Physical Therapy in Sport*. 2002;3(2):88-96.
93. Cormie P, McGuigan MR, Newton RU. Developing maximal neuromuscular power: part 2 - training considerations for improving maximal power production. *Sports Med*. 2011;41(2):125-146.
94. Newton RU, Kraemer WJ. Developing explosive muscular power: implications for a mixed methods training strategy. *Strength Cond J*. 1994; 16: 20-31.
95. Lovell DI, Cuneo R, Gass GC. The effect of strength training and short-term detraining on maximum force and the rate of force development of older men. *Eur J Appl Physiol*. 2010;109(3):429-435.
96. Mangine GT, Ratamess NA, Hoffman JR, et al. The effects of combined ballistic and heavy resistance training on maximal lower- and upper-body strength in recreationally trained men. *J Strength Cond Res*. 2008;22(1):132-139.
97. Bride JM, Triplett-McBride T, Davie A, et al. The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. *J Strength Cond Res*. 2002;16(1):75-82
98. Kaneko M, Fuchimoto T, Toji H, at al. Training effect of different loads on the force-velocity relationship and mechanical power output in human muscle. *Scandinavian Journal of Medicine & Science in Sports*. 1983;5:50-55.
99. Moss BM, Refsnes PE, Abildgaard A, at al. Effects of maximal effort strength training with different loads on dynamic strength, cross-sectional area, load-power and load-velocity relationships. *Eur J Appl Physiol Occup Physiol*. 1997;75(3):193-199.
100. Young, K., Gabbett, TJ., Haff**,** G, et al. The effect of initial strength levels on the training response to heavy resistance training and ballistic training on upper body pressing strength. *Journal of Australian Strength and Conditioning*. 2013; 21(8):85-87.
102. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. *Sports Med.* 2005;35(10):841-51.
103. Kawamori N, Crum AJ, Blumert PA, et al. Influence of different relative intensities on power output during the hang power clean: identification of the optimal load. *J Strength Cond Res*. 2005; 19(3): 698-708.
104. Baker D, Newton RU. Methods to increase the effectiveness of maximal power training for the upper body. *Strength Cond J.* 2005; 27(6): 24-32.
105. Cormie P, McCaulley GO, Triplett NT, et al. Optimal loading for maximal power output during lower-body resistance exercises. *Med Sci Sports Exerc*. 2007 Feb;39(2):340-9.
106. Cormie P, McCaulley GO, McBride JM. Power versus strength-power jump squat training: influence on the load-power relationship. *Med Sci Sports Exerc.* 2007. 39(6):996-1003.