CHAPTER 1

Periodization of Resistance Training

Many people performing resistance training, whether they are fitness enthusiasts or professional athletes, have reached points in their training at which little or no increase in muscle size, power, or strength occurs. Such a training plateau occurs even though they train intensely. Training plateaus have most likely occurred since athletes started serious training. Likewise, probably since athletes started serious training, they and their coaches have made changes in their training programs in an attempt to bring about continued fitness gains and avoid training plateaus. With experience, coaches and athletes have learned what changes to make in training programs and when to implement those changes. The changes made resulted in the development of planned long-term training programs and planned changes in training programs. Terms to describe planned long-term training variation are *cycling, chronic program manipulation,* and *periodization. Periodization* is the most popular term for planned training variation.

Changes in resistance training in virtually any acute program variable can be used as part of a periodized training plan. Thus choice of exercise, order of exercise, number of repetitions per set, number of sets, lengths of rest periods between sets and exercises, and intensity of exercises can all vary in a program. In addition, the number of training sessions per day, the velocity of training, the number of training sessions per week, and planned short-term (e.g., 1-2 weeks) rest breaks or low-intensity or low-volume training periods can all be incorporated into a periodized training program. Although all of these types of changes can be made, changes in training volume (i.e., number of sets, number of repetitions per set, training sessions per week, training sessions per day) and training intensity (i.e., percent of the maximal resistance that can be used for 1 repetition) have

From the perspectives of health, fitness, and performance, there are many reasons to use a periodized resistance training program.

The 2005 International Powerlifting Federation World Championships. Photo courtesy of Disa L. Hatfield.

received the most study by sport scientists and are typically used as the basis of any periodized training program.

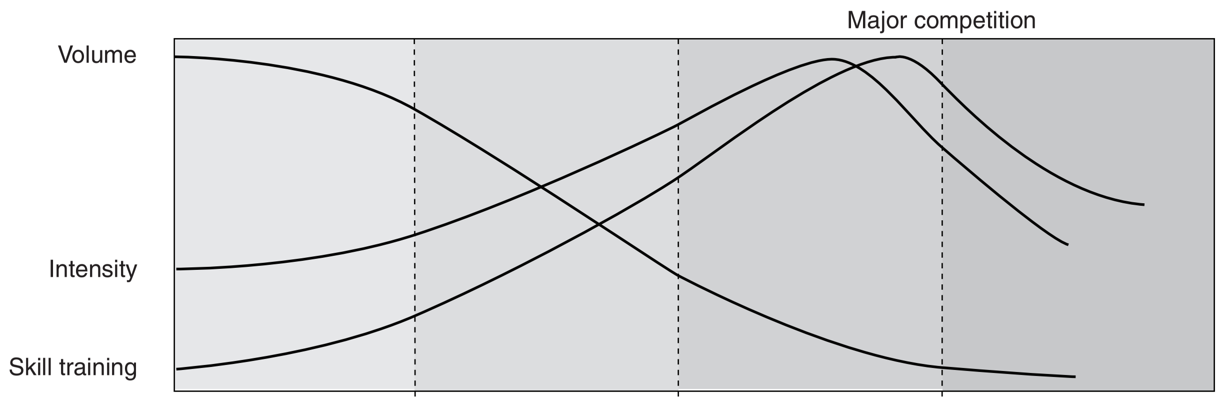
Besides continued long-term gains in muscle size, strength, and power, there are other reasons to use a periodized resistance training program. Planned variation in training for many individuals will also help keep the training program psychologically interesting. If a trainee simply goes through training sessions and does not attempt to perform the session at the needed intensity and volume because of boredom, fitness gains will stagnate. Another reason to use a periodized training program is the prevention of overuse injuries. Performing the same exercises at the same training intensity and volume for long periods can eventually result in an overuse injury.

EASTERN EUROPEAN INFLUENCE ON PERIODIZED TRAINING

Anecdotal evidence indicates that some American weightlifters were using periodized training as early as the 1960s. However, coaches, athletes, and sport scientists from the former Eastern Bloc countries are normally credited with developing and researching the concepts of periodized training. The goal of elite athletes is to peak, or have the best possible performance, at major competitions, such as national championships, world championships, or the Olympic Games. So one original major goal of periodized training, including periodized resistance training, was to ensure peaking for major competitions. For resistance-trained athletes, such as Olympic weightlifters and shot putters, that meant that maximal strength and power must peak for major competitions. For the goal of peaking to occur, the training program had to ensure that strength and power were optimally developed, muscular hypertrophy occurred, and there was adequate recovery between training sessions so that successive training sessions could be performed at high intensity.

It may be that part of the success and domination of athletes in former Eastern Bloc countries in some sports indicates that periodized training does result in strength and power gains over a year of training and even over the careers of athletes. One of the concepts of periodized training was training variation. Thus the training program had to provide variation in the psychological and physiological stress of physical conditioning and competition. This was necessary in order to bring about the adaptations needed for long-term increases in the physical condition of an athlete that were critical for success in his or her particular sport. Training variation, such as progressing toward greater training intensities, was also essential for peaking the athlete for major competitions.

Sport scientists and coaches from the former Eastern Bloc carefully monitored their athletes' training volume and intensity and came to the conclusion that training volume and intensity of successful athletes followed a particular pattern over the course of a training year (see figure 1.1). At the start of the competitive year when preparation for competition was just beginning, training volume was high and training intensity low. As the competitive year progressed, training volume decreased and training intensity increased. Before major competitions, training intensity was at its highest and training volume was at its lowest. Additionally, training intensity also showed a decrease immediately before major competitions. This decrease in training volume and intensity was thought to be necessary for psychological as well as physical recovery immediately before a major competition so that the best possible performance would occur at the major competition. Skill training for the particular sport also showed a pattern similar to that of training intensity. However, skill training peaked slightly closer to the major competition than training



European terminology	Preparation phase	First transition	Competition phase	Second transition (active rest)
Traditional American terminology	Pre-season		In-season	Off-season
American strength and power terminology	Hypertrophy	Strength and power	Peaking	Active rest

Figure 1.1 Training intensity and volume pattern with strength and power periodization.

Reprinted, by permission, from S.J. Fleck and W.J. Kraemer, 2004, *Designing resistance training programs,* 3rd ed. (Champaign, IL: Human Kinetics), 213.

intensity did. But similar to training intensity, skill training decreased immediately before major competitions. This general pattern of skill training, intensity, and volume was used in developing training programs for particular sports and individualized training programs for each athlete.

Originally, because there were relatively few major competitions in a competitive year, the pattern of increasing training intensity and decreasing training volume of one training cycle took place over an entire year. Then, as more competitions were added to the competitive year, the time frame for completing an entire training cycle was gradually shortened. Today, the entire pattern of decreasing training volume and increasing intensity takes place in 3 to 4 months. Thus the entire pattern is repeated three or four times per year. As the year progresses, training intensity and volume ideally are progressively higher at the start of successive training patterns than they were at the start of previous patterns because the athlete is now in better physical condition. Likewise, as the pattern is repeated over an athlete's career, training intensity and volume at the start of each year are also higher because physical condition during the athlete's career also increases.

The complexity of periodized strength training has evolved to meet the needs of particular sports and guarantee the success of individual athletes. However, periodization is still based in the concepts of training variation, sport specificity, and individualization of the training program.

CLASSIC STRENGTH AND POWER PERIODIZATION

Intensity and volume of weight training for classic strength and power periodization follow the pattern developed by the sport scientists and coaches from the former Eastern Bloc (figure 1.1). If this pattern of training intensity and volume is outlined in terms of sets of an exercise and repetitions per set, many variations are possible. One popular variation is presented in table 1.1. The changes in the repetitions per set account for the greatest change in training intensity and volume. The recommended repetitions per set are supposed to be performed with the use of repetition-maximum weights (RM) or very close to RM weights. Typically after an athlete completes the entire training cycle, a short period (1-2 weeks) of active recovery consisting of low-intensity and low-volume weight training, no weight training, or

Table 1.1 Classic Strength and Power Periodization Model

Training phase		Hypertrophy	Strength	Power	Peaking	Active recovery
Workout variables	Sets	3-5	3-5	3-5	1-3	Light physical activity
	Repetitions/set	8-12	2-6	2-3	1-3	
	Intensity	Low	Moderate	High	Very high	
	Volume	Very high	High	Moderate	Low	

light physical activity takes place. This allows both psychological and physiological recovery in preparation for the next training cycle.

The active recovery phase does not necessarily mean complete cessation of all training; this phase is typically relatively short in length. If all training ceased for a long period, detraining, or loss of training adaptations, would occur. If the active recovery phase is too long, the trainee would enter the next training cycle in a physical condition at or significantly below where he or she started the cycle just completed. This potentially means that the trainee will be in no better physical condition as the years of training progress. The length of the active recovery phase also depends in part on the individual needs of the trainee. For example, an active recovery phase several weeks in length for a veteran international-class athlete who has just won a world championship medal may not be detrimental to the upcoming competitive year. However, an active recovery phase of similar length for a less experienced athlete who is trying to become competitive at the international level and is just starting to prepare for a world championship may not be beneficial.

As the concepts of classic strength and power periodization developed and research in sport science was performed concerning the efficacy of this training pattern, specific terminology was developed to describe various time periods or training phases within a periodized training program. Macrocycle typically refers to 1 year of training. Mesocycle refers to 3 to 4 months of a macrocycle. Using the European terminology, the preparation phase, first transition phase, competition phase, and second transition phase would all be mesocycles. A microcycle refers to 1 to 4 weeks of training within a mesocycle, although today many people use *microcycle* to refer specifically to 1 week of training.

Traditional American terminology also can be applied to the strength and power periodization model. The preseason corresponds to the preparation and first transition phase of the European terminology. In-season corresponds to the competition phase, and the off-season corresponds to the second transition and active recovery phases. When describing the classic strength and power periodization model, Olympic weightlifters and similar athletes, such as shot putters, use a slightly different terminology than the traditional American terminology, called the American strength and power terminology. The American strength and power terminology is used in table 1.1 to describe various training phases of the strength and power periodization model. Each training phase, no matter what terminology is used, has specific training goals. For example, the preparation phase is used for developing muscle hypertrophy and strength in preparation for the transition (first transition phase) to power and maximal strength development necessary for success during the competition phase. These same goals are applied to the traditional American term *preseason*. The American strength and power terminology perhaps is the most descriptive of the training goals of each training phase. The goals during the strength and hypertrophy phases are to develop strength and muscle size, respectively, while goals of the strength and power phases are to develop maximal strength and power, respectively. Although maximal strength, power, and hypertrophy are related within the context of the American strength and power terminology as the number of repetitions per set decrease, there is a gradual switch toward development of maximal, or one-repetition maximum (1RM), strength and power. Thus the major goal of the peaking phase is to develop maximal, or one-repetition maximum, strength and power. The goal of the classic strength and power model is to develop maximal (1RM) strength and power, which are necessary for success in sports such as Olympic weightlifting and discus throwing. This goal is in part accomplished by a gradual change to lifting heavier and heavier weights for fewer repetitions. The goal of emphasizing power as the training cycle progresses is also typically accomplished by changes in the exercises performed. Thus as the training cycle progresses, fewer sets of the back squat and more sets of the power clean or power snatch might be performed.

The training phases presented for the American strength and power terminology do allow variation within each phase and a gradual switch in training emphasis or goals as the training phase progresses. For example, during the strength phase, repetitions per set at the beginning of the phase would be 5 or 6, whereas at the end of the phase

Snatches and snatch variations like the power snatch pull require the development of power in order to be successfully completed.

repetitions per set might be in the range of 2 to 4. This means that training intensity has increased while training volume has decreased. The number of sets within each training phase also allows for changes in training volume. For example, on one day in the strength phase, the back squat might be performed for 5 sets while on another day only 3 sets might be performed. These types of training emphases change by performing different exercises, and variation in training intensity and volume can be applied to all training phases.

EFFICACY OF CLASSIC STRENGTH AND POWER PERIODIZATION

When examining any training program, including resistance training programs, the first question that should be asked is whether the resistance exercise program causes the desired physiological adaptations. For resistance training programs, that includes increases in strength, local muscular endurance, muscle hypertrophy, and power. The next question is whether the program results in greater increases in those variables compared to the increases with other training programs. The answer to these questions concerning the classic strength and power periodization model is yes. Qualitative reviews (Fleck, 1999; Fleck, 2002) conclude that the majority of research projects demonstrate that the classic strength and power model brings about greater increases in maximal strength and power than low-volume (single-set) and higher-volume (3-6 sets), nonvaried (same number of sets and repetitions per set for the entire training period) training programs. Meta-analyses also conclude that periodized resistance training brings about greater increases in strength than nonvaried training programs (Rhea & Alderman, 2004). The majority of studies on periodization in this meta-analysis are variations of the strength and power periodization model, although a few of the studies use other periodization models (i.e., nonlinear models). A meta-analysis is a statistical procedure by which the results of all studies examining a particular topic, such as periodized weight training compared to nonvaried training models, can be statistically analyzed and a quantitative conclusion reached.

Not only does strength and power periodization result in greater strength and power increases than nonvaried models, but the majority of studies also indicate that this type of training brings about greater increases in fat-free mass, indicating greater muscle hypertrophy and greater decreases in percentage of body fat than nonvaried training models (Fleck, 1999; Fleck, 2002). Fewer studies have examined body composition changes due to strength and power periodization than studies examining strength and power changes, so conclusions concerning body composition changes must be viewed with some caution. It is important, however, to note that whenever a significant difference between strength and power periodization and nonvaried models occurs, it is always in favor of the periodized training program.

Figures 1.2 and 1.3 present the maximal strength results of one study comparing the strength and power periodization model to two nonvaried training models. Training was performed 3 days per week for 16 weeks. The two nonvaried models were 5 sets of 10 repetitions at approximately 79% of 1RM and 6 sets of 8 repetitions at approximately 83% of 1RM. The periodized program consisted of four 4-week training phases. The training phases were 5 sets of 10 repetitions at approximately 79% of 1RM, 6 sets of 8 repetitions at approximately

83% of 1RM, 3 sets of 6 repetitions at approximately 88% of 1RM, and 3 sets of 4 repetitions at approximately 92% of 1RM. Bench press and squat 1RM were determined every 4 weeks. In the bench press (figure 1.2), the periodized program demonstrated superiority at 8, 12, and 16 weeks of training compared to the two nonvaried programs. Both nonvaried programs appear to be in a training plateau from week 4 to week 12. Both nonvaried programs also demonstrated relatively small percentages of increase in bench press 1RM compared to the strength and power periodization training.

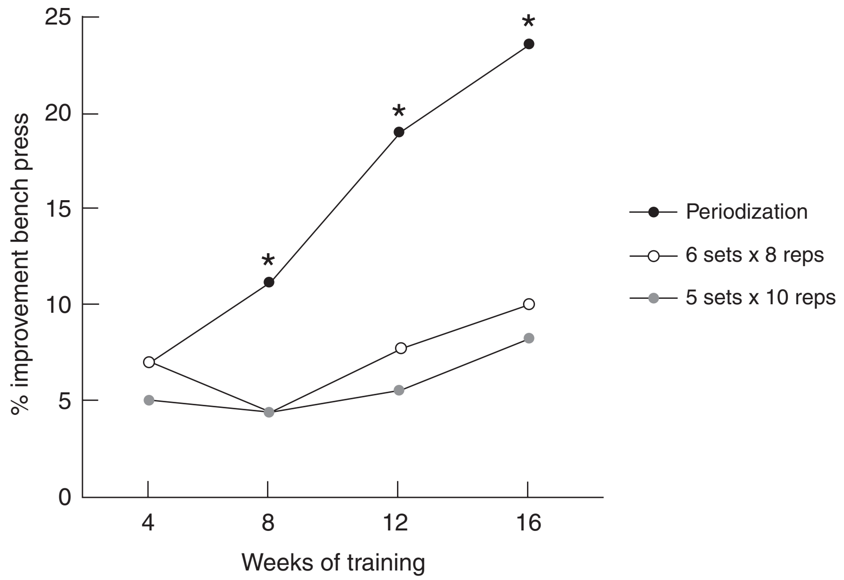


Figure 1.2 Results of a study comparing the strength and power periodization model to two nonvaried training programs for gains in the bench press in American football players. * = Significant difference from nonperiodized programs.

Data from D.S. Willoughby, 1993, "The effects of meso-cycle-length weight training programs involving periodization and partially equated volumes on upper and lower body strength," *Journal of Strength and Conditioning Research* 7:2-8.

In the squat (see figure 1.3), the periodized model and the 6 sets of 8 repetitions training model both showed significantly greater gains than the 5 sets of 10 repetitions after 4, 8, and 12 weeks of training. However, it was not until after 16 weeks of training that the periodized model showed a significantly greater gain in squat 1RM than both of the nonvaried training programs. The results demonstrate several important aspects of strength increases due to weight training. Not all muscle groups or exercises will respond to the same extent (i.e., period-

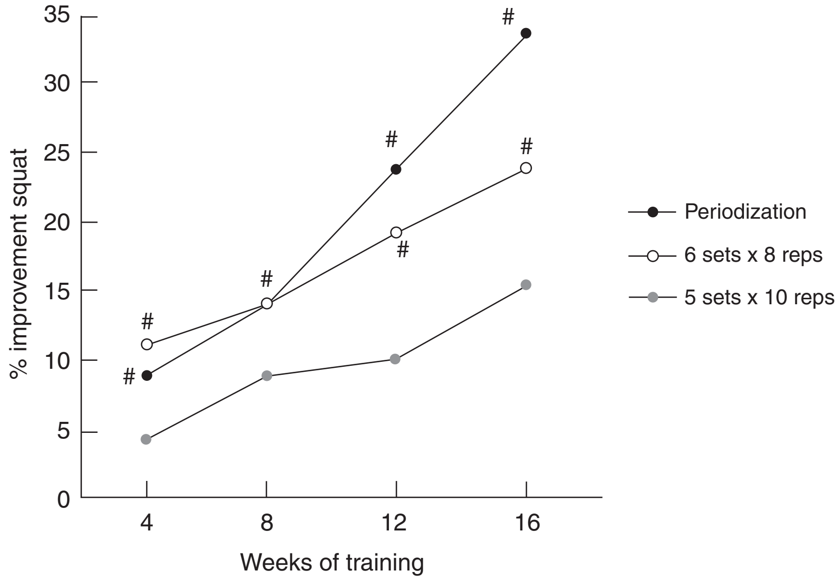


Figure 1.3 Results of a study comparing the strength and power periodization model to two nonvaried training programs for gains in the squat exercise in American football players. * = Significant difference from nonperiodized programs. # = Significant difference from 5 sets of 10 repetitions program.

Data from D.S. Willoughby, 1993, "The effects of meso-cycle-length weight training programs involving periodization and partially equated volumes on upper and lower body strength," Journal of Strength and Conditioning Research 7:2-8.

ized bench press increased approximately 24% while squat increased approximately 34%) or in the same time frame to a training program. Over short training periods (4 weeks in bench press and 12 weeks in squat), periodized training may not show superiority over nonvaried programs. Additionally, in order for physiological adaptations to occur, such as muscle hypertrophy and optimal neural recruitment resulting in strength gains, sufficient training time must be allowed, and the time necessary for training models to show different results (if they exist) may not be the same for different muscle groups.

The mechanisms resulting in greater strength gains caused by periodized training are not completely elucidated. However, a meta-analysis concludes that the effectiveness of periodized training is independent of the performance of greater volume or intensity with periodized training compared to nonvaried programs (Rhea & Alderman, 2004). Additionally, variations in training, independent of increases in training volume and intensity, may increase the overload experienced by the neuromuscular system by continually applying an unaccustomed training stress, which may result in greater fitness gains. With periodized training, the unaccustomed training stress occurs when the number of repetitions per set or number of sets of an exercise changes from one training phase to the next and within each training phase. Although the mechanisms by which strength and power periodized training brings about greater increases in strength, power, and changes in body composition than nonvaried training models are not completely clear, it is clear this type of training is more effective than nonvaried training models.

NONLINEAR PERIODIZATION

The exact origin of nonlinear periodization, also termed *undulating periodization,* is unclear, but it is a more recent development than the classic strength and power periodization model. Nonlinear programs may have originated in the late 1980s with 2-week training periods using various training zones to meet the needs of athletes (Poliquin, 1988). Likewise, nonlinear programs may have originated in the late 1970s and early 1980s with strength coaches designing programs to meet the needs of American football players. In these training plans, two very different types of training days were developed. The different training days were termed hypertrophy and functional strength days. On the functional strength days, multijoint exercises (power clean, squat) were performed using lower numbers of repetitions (4-6 repetitions per set), while on the hypertrophy days more single-joint exercises (arm curls, knee curls) were performed using higher numbers of repetitions (8-12 repetitions per set). Additionally, it was noted that when more mesocycles were used in a macrocycle, better results were achieved. Essentially that meant that the different patterns of loading had a greater frequency of exposure as microcycles shifted from 4 weeks to 2 weeks; some now use 1-week microcycle changes.

Although many variations of the nonlinear training model can be developed to meet the needs and goals of a trainee, the following is a representative model. If weight training is performed 3 days per week, three different RM training intensities, or repetition maximum (RM) zones, will be used on each of the 3 training days. On the first, second, and third training day of the week, training zones of 4 to 6, 12 to 15, and 8 to 10 repetitions per set using RM resistances will be performed, respectively. Other training zones, such as a very heavy (1- to 3RM) zone, can be included in the training program's design

On a hypertrophy workout day, predominantly single-joint exercises, such as arm curls, are performed using higher numbers of repetitions (8-12) per set.

if they meet the needs and goals of the trainee. In addition, percentages of the 1RM can be used for certain lifts addressing the same types of loading ranges. Care must be taken because the percentage of 1RM and the RM vary depending on the muscle mass involved in an exercise and for machines versus free weights (e.g., 80% of 1RM in a squat may result in only 8 to 10 repetitions, whereas in the leg press 15 to 20 repetitions may be possible at the same percentage of 1RM) (Hoeger et al., 1987; 1990; Shimano et al., 2006).

Note that training zones are *not* necessarily performed sequentially such that training volume and intensity follow a consistent pattern of increasing or decreasing over time. For example, during 1 week of training, the zones might be performed in the sequence of 4 to 6, 12 to 15, and 8 to 10 repetitions per set. During the next week of training, the sequence of zones might be 8 to 10, 4 to 6, and 12 to 15 repetitions per set. With nonlinear training, long periods (weeks) using the same training intensity and volume are not performed. Thus the need for a high training volume phase (hypertrophy phase), as used in the classic strength and power model, is avoided. Another advantage of the nonlinear model is ease of administration. Once training zones have been chosen that meet the goals of the training program, they are simply alternated on a session-by-session basis. So continuing with the current example, if, during the course of a season during one week only two weight training sessions can be performed because of a competition, the first training session of the next week might use the training zone that was not used during the previous week and the sequence of training zones begins with that training zone. There are other possible ways to make the decision concerning which training zone to use, such as if there is lingering fatigue resulting from the weekend competition, which minimizes the ability to develop maximal power. In that case if a power training zone is part of the training program, it might be advisable to use a different training zone for the first training session of the week after the competition.

However, once training zones have been decided, it does not mean that over time different training zones cannot be incorporated into the training program. For example, during the early preseason, a very heavy or a power training zone might not be used. But, during the late preseason, a very heavy or power training zone might be used. Thus the choice of training zones to use at a particular point in the training program can be changed to meet the goals and needs of the trainee as training progresses. Similar to the classic strength and power training model, planned light training periods or rest periods can also be incorporated into nonlinear training programs. Typically these recovery periods are scheduled approximately every 12 weeks of training.

Nonlinear periodization offers advantages over classic strength and power periodization in some training situations. A major goal of the strength and power periodization model is to reach a peak in strength and power at a particular time. For many sports with long seasons, such as basketball, volleyball, tennis, ice hockey, and baseball, success is dependent on physical fitness and performance throughout the season. When resistance training for general fitness, peaking maximal strength and power at a certain point may not be important, but continued gains in strength and power are important training outcomes. Training goals for many sports and for general fitness need in part to focus on development and maintenance of physical fitness throughout the season or throughout the year. For sports with long seasons, peaking maximal strength and power at the end of the season in preparation for major competitions, such as conference tournaments or other major tournaments, is important. However, using the classic strength and power periodization model for those sports presents some difficulties. If a classic strength and power model is used as a program approach in the off-season and preseason, the peaking phase will occur at the start of the competitive season. This may ensure the best possible performance at the start of the competitive season; however, strength and fitness must be maintained throughout the season. If the peaking phase occurs at the end of the competitive season in preparation for major competitions or tournaments, then high-volume resistance training must be performed during the beginning of the competitive season. That may result in less-than-optimal performance at the beginning of the season because of fatigue and could result in losses in early competitions. If those early games are lost, qualification for tournaments at the end of the season may be jeopardized. Thus the application of the classic strength and power periodization training model for many sports and activities presents some difficulties in the training program's design.

Nonlinear periodization is more flexible in how and when a peak in performance is created, depending on the goals of a particular mesocycle. It also allows for more frequent exposure to different loading stimuli (e.g., moderate, power) within a particular weekly workout profile. It does not progress in a planned linear increase in intensity with a reduction in volume as seen in the linear model, but it varies training volume and intensity in such a way that consistent fitness gains occur over long training periods.

EFFICACY OF NONLINEAR PERIODIZATION

Studies have examined the efficacy of nonlinear periodization. To date, all studies indicate that it does result in significant fitness gains and results in greater gains than other training models provide. The earliest of the studies was 24 weeks in length. It involved training Division III collegiate football players and compared a session-to-session nonlinear pattern to a low training volume one-set training model (Kraemer, 1997). The one-set program consisted of training 3 days per week using two different groups of exercises on alternating training days and forced repetitions. The nonlinear training model consisted of training 4 days per week using two different training sessions alternated on a training-session basis. One training session was a strength and power session and consisted of primarily multijoint exercises using a 3- to 5-, an 8- to 10-, or a 12- to 15RM training zone. The other session was a hypertrophy session and consisted of both single-joint and multijoint exercises always using an 8- to 10RM training zone. The nonlinear model resulted in significantly greater gains in tests of strength, local muscular endurance, and power (table 1.2). Although both training programs resulted in a significant decrease in percentage of body fat, the nonlinear model resulted in a significantly greater decrease (nonlinear 17.9% to 12.0%; single-set model 17.1% to 15.9%). Both training models also resulted in a significant increase in total body mass. However, again the nonlinear model resulted in a significantly greater gain in body mass (nonlinear model 104 kg to 111 kg; single-set model 103 kg to 104 kg) than the single-set model.

Women's Division I tennis players have been trained using the nonlinear model, and the results were compared to a nonvaried, low-volume one-set model and a higher-volume three-set model. In the first of these studies a one-set circuit program of 8 to 10 repetitions at an 8- to 10RM resistance performed 3 days per week was compared to a nonlinear model performed 4 days per week over 9 months of training (Kraemer et al., 2000). Both groups of tennis players trained 2 or 3 days per week depending on their competitive schedules. The nonlinear model consisted of performing 2 to 4 sets using training zones of 4 to 6, 8 to 10, and 12 to 15 repetitions per set alternated on a session-by-session basis. Both groups performed the same series of single-joint and multijoint exercises. The nonlinear model generally used all three training zones only for the multijoint exercises, while the single-joint exercises were always performed using 8 to 10 repetitions per set. The resistance used in the nonlinear model was adjusted to allow only the desired number of repetitions per set (RM training zone). The nonlinear model demonstrated a greater percentage of gains in measures of strength and power than the single-set model (table 1.2). A significant decrease in percentage of body fat (nonlinear 22 to 18%; single set 22 to 21%) and an increase in fat-free mass were shown by the nonlinear model, while the single-set model showed no significant changes in these measures. Perhaps most important, the nonlinear model demonstrated a significant increase of 30% in serve velocity while the single-set model demonstrated a nonsignificant change of 4% in serve velocity. It is also important to note that in the majority of test variables, the nonlinear model demonstrated significant increases from pretraining to 4 months of training, from 4 months to 6 months of training, and from 6 months to 9 months

Table 1.2 Nonlinear Training Studies

Reference	Mean age (yrs) and sex	Training length	Frequency per week	Sessions	Intensity	Exercises trained	Tests	Percentage of increase
Kraemer, 1997		24	3	Sets: 1 Repetitions: 8 to 10 with forced reps	8- to 10RM	20	Bench press Leg press Bench press reps at 80% 1RM Leg press reps at 80% 1RM Vertical jump Wingate power	13* 6* 37* 22* 7* 5*
			4	Undulating periodization strength session Sets: 2 to 4 Repetitions: 12 to 15, 8 to 10, 3 to 5 Hypertrophy session Sets: 2 to 4 Repetitions: 8 to 10	12- to 15-, 8- to 10-, 3- to 5RM 8- to 10RM	21	Bench press Leg press Bench press reps at 80% 1RM Leg press reps at 80% 1RM Vertical jump Wingate power	29*a 20*a 56*a 41*a 23*a 55*a
Kraemer et al., 2000	19 F	36	2 or 3	Sets: 1 Repetitions: 8 to10	Close to 8- to 10RM	14	Bench press Shoulder press Leg press Wingate power Vertical jump	10* 14* 7* 1 5

(continued)

Table 1.2 *(continued)*

Reference	Mean age (yrs) and sex	Training length	Frequency per week	Sessions	Intensity	Exercises trained	Tests	Percentage of increase
			2 or 3	Undulating periodization Sets: 3, 2, or 4 Repetitions: 4 to 6, 8 to 10, or 12 to 15	Close to RMs	14	Bench press Shoulder press Leg press Wingate power Vertical jump	25* 28* 18* 14* 48*
Marx et al., 2001	22-23 F	24	3	Sets: 1 Repetitions: 8 to 12	8- to 12RM	2 alternating groups of 10 exercises	Bench press Leg press Bench press reps at 80% 1RM Leg press reps at 80% 1RM Wingate power Sit-ups in 1 min Vertical jump 40 yd sprint	12* 11* 10* 19* 4 13* 10* +1

			4	Undulating periodization strength sessions/wk Sets: 2 or 3 Repetitions: 3 to 5, 8 to 10, or 12 to 15 Hypertrophy sessions Sets: 2 or 3 Repetitions: 8 to 10	3- to 5-, 8- to 10-, or 12- to 15RM 8- to 10RM	Undulating sessions 7 Constant 8 to 10 reps Session 12	Bench press Leg press Bench press at 80% 1RM Leg press reps at 80% 1RM Wingate power Sit-ups in 1 min Vertical jump 40 yd sprint	47[*a] 32[*a] 24[*a] 64[*a] 27[*a] 42[*a] 40[*a] –6[*a]
Kraemer et al., 2003		36	2 or 3	Nonvaried Sets: 2 or 3 Repetitions: 8 to 10	8- to 10RM	3 alternating groups of 11 or 12 exercises	Bench press Leg press Wingate power Vertical jump	17[*] 17[*] 18[*] 37[*]
			2 or 3	Undulating periodization alternating sessions Sets: 2 or 3 Repetitions: 4 to 6, 8 to 10, or 12 to 15	4- to 6, 8- to 10, or 12- to 15RM	3 alternating groups of 11 or 12 exercises	Bench press Leg press Wingate power Vertical jump	23[*] 19[*] 12[*] 50[*b]

[*] = Significant change pre- to posttraining.

[a] = Significant difference from 1-set group.

[b] = Significant difference from nonvaried group.

of training. The single-set model demonstrated a significant increase from pretraining to 4 months of training and then showed no further significant change or was in a training plateau.

The second study training female Division I tennis players compared the nonlinear model to a nonvaried three-set model over 9 months of training (Kraemer et al., 2003). The three-set model always trained using 8 to 10 repetitions per set at RM resistances. The nonlinear model trained with three sets using three alternating training zones on a session-by-session basis of 4 to 6, 8 to 10, and 12 to 15 repetitions per set at RM resistances. Both groups trained 2 or 3 days per week, depending on their competitive schedules. Few significant differences in strength and power were noted between groups after the 9 months of training (table 1.2). However, whenever a significant difference between groups was noted, it was in favor of the nonlinear training model. Additionally, testing was performed after 4, 6, and 9 months of training; whenever a significant difference was noted between groups at those time points it was in favor of the nonlinear model. It is also important to note that the nonlinear model showed a greater number of significant gains between pretraining and 4 months training, 4 to 6 months of training, and 6 to 9 months of training, indicating more consistent fitness gains as the training progressed. Both groups also demonstrated significant increases in fat-free mass and decreases in percentage of body fat; no significant differences were noted between groups. Perhaps most important to this group of athletes, the nonlinear program resulted in significantly greater increases (22 to 36%) in serve, backhand, and forehand velocities compared to the nonvaried training increases of 14 to 17% in the same sport-specific measures.

The nonlinear model has also been compared to a low-volume single-set model in the training of typical college-aged females over 6 months (Marx et al., 2001). The single-set group trained 3 days per week using 8 to 10 repetitions per set at RM resistances. Two different circuits were performed by the single-set model on an alternating session-by-session basis. The nonlinear group trained 4 days per week with 2 to 4 sets. Two days per week a strength session composed of primarily multijoint exercises was performed with the use of alternating training zones of 3 to 5, 8 to 10, and 12 to 15 repetitions per set at RM resistances. The other two training sessions per week were hypertrophy training sessions performed always for 8 to 10 repetitions per set at RM resistances. At the end of the 6 months of training, the nonlinear group demonstrated significantly greater increases in measures of strength, power, and motor performance than the nonvaried group (table 1.2). The nonlinear group also demonstrated significantly greater increases in fat-free mass (8 vs. 2%) and percentage of body fat (–7 vs. –2.5%) than the single-set group. Additionally, in the majority of variables, the nonlinear training group demonstrated significant changes from pretraining to 4 months of training and from 4 months of training to 6 months of training while in all variables the single-set group demonstrated significant gains from pretraining to 4 months of training with no significant increase from 4 to 6 months of training. This shows that the nonvaried training resulted in a training plateau after 4 months of training while the nonlinear training showed continued fitness gains over the 6 months of training, which underscores the efficacy of nonlinear training.

Nonlinear periodization has even been shown to be effective during a competitive season. Silvestre and colleagues (2006) demonstrated that strength and power can be maintained or even increased with a nonlinear resistance training protocol over a competitive soccer season. Such uses of the nonlinear method enhance the ability of athletes to physically develop their bodies—even during a competitive season, when detraining can occur.

Collectively these studies demonstrate that the nonlinear training model results in significantly greater changes in body composition, strength, and power than nonvaried training models. These changes with the nonlinear training model are consistent and progressive even after months of training. Additionally, changes in fitness parameters are apparent in untrained individuals as well as in trained athletes.

EFFICACY OF SESSION-BY-SESSION VARIATION

One aspect of any periodized training program that needs to be considered is how often training intensity and volume should be changed. With nonlinear resistance training, volume and intensity are changed dramatically from one training session to the next. Some insight concerning the efficacy of using session-to-session changes in training volume and intensity, such as used in nonlinear periodization, can be gained by examining the results of several studies. The first of these studies compared strength gains during training with the use of a classic strength and power model, a nonvaried multiset model, and a biweekly nonlinear model over 12 weeks (Baker et al., 1994). With a biweekly nonlinear model, three training zones are used, but rather than alternately use training zones on a session-by-session basis, training zones are alternated every 2 weeks. Although all groups significantly improved in bench press 1RM (12-16%) and squat 1 RM (26-28%), no significant differences were observed between the groups. Results indicate that a biweekly nonlinear periodization model and a classic strength and power model result in similar changes in strength.

The second study compared a session-by-session nonlinear program with a classic strength and power periodization program over 12 weeks of training (Rhea et al., 2002). Both groups trained 3 days per week and performed three sets of each exercise per training session. The nonlinear program performed one session per week at 8, 6, and 4RM resistances. After the 12 weeks of training, the session-by-session nonlinear program resulted in significantly greater increases in bench press 1RM (29 vs. 14%) and leg press 1RM (56 vs. 26%) than the strength and power periodized model, indicating session-by-session nonlinear programs result in greater strength increases than a variation of the classic strength and power training model.

Collectively these two studies indicate that a session-by-session nonlinear program results in greater strength gains than a classic strength and power model, while a biweekly nonlinear program results in significant but equivalent strength gains compared to a variation of the classic strength and power model. Although comparison of results from two separate studies is tenuous, results of these two studies suggest session-by-session nonlinear programs cause greater strength gains than biweekly nonlinear programs.

IMPETUS FOR THE FLEXIBLE NONLINEAR APPROACH TO PERIODIZATION

As discussed previously, research supports the use of a classic strength and power training model. Anecdotal evidence also supports the classic strength and power periodization model and a reduction in the number of mesocycles in the macrocycle indicating that a greater variation in volume and intensity appears to be beneficial to the training adaptations. Several other factors also spurred the growth of nonlinear periodization methods at the grassroots level. Personal trainers always try to keep workouts exciting to their clients and have discovered that their clients need more variation in training routines to keep boredom at a minimum. Finally, the physical and mental challenges that athletes face outside of the weight room also demand a training system that responds to athletes' immediate needs for training on a given day.

Consequently, the practicality and increasing popularity of the nonlinear approach to periodized resistance training have been due to several factors:

1. It allows more variety in a workout sequence.
2. It allows athletes to more quickly pick up a workout sequence after illness or injury.
3. It causes less boredom in the day-to-day workout routines.
4. It is adaptable to the diverse situations of a given training day and gives trainees the most effective type of workout.
5. It allows more frequent rest of some muscle tissue due to the use of various resistance loadings.

One possible problem associated with any training program is determining whether a trainee can perform the scheduled session with the desired training volume and intensity. To help address this question, researchers working with the University of Connecticut men's and women's basketball players in 2001 to 2004 showed that new variations in the nonlinear approach to periodization of resistance training were successful and that even newer variations of nonlinear periodization were still possible. This work resulted in what has been termed *flexible nonlinear periodization.* The flexible nonlinear approach allows for the trainer and athlete to choose the workout when the athlete reports to the weight room. While still in an experimental stage of development, the practical concept consists of several steps:

1. Conducting a coaching analysis of the athlete's fatigue status at the time of the workout
2. Testing for physical performance status on the day of the workout
3. Monitoring of the initial resistance and set performances in the workout compared to prior efforts
4. Choosing, modifying, or switching the workout based on the results of steps 1 to 3
5. Having an overall plan for the mesocycle so that workouts in a 7- to 10-day cycle can be checked off or accomplished

In sports, more frequent variation was needed for the longer-season sports, such as basketball, tennis, hockey, and wrestling, in which athletes could not peak for just a single competition.

Both nonlinear periodization and flexible nonlinear periodization have advantages over other weight training programs that make them applicable to a variety of training situations and populations. These populations include both fitness enthusiasts as well as various groups of athletes.

SUMMARY

Eastern European coaches and sport scientists are normally credited with developing the concepts of periodization of training, including the classic strength and power periodization of resistance training model. Classic strength and power periodization of resistance training follows a general pattern of decreasing training volume and increasing training intensity as a training cycle progresses. Sport science research demonstrates the classic strength and power periodization training model does result in greater fitness gains than nonvaried resistance training can provide. Although nonlinear periodization is a relatively new strength training model, it does result in significant gains in strength, power, body composition, and motor performance. Data also indicate that nonlinear periodization results in significantly greater changes in fitness variables compared to nonvaried and even strength and power training models. Current research indicates that when a nonlinear program is used, the training zones should be alternated on a session-by-session basis. Building on the concepts of training variation used with classic strength and power periodization of resistance training, both the nonlinear periodization training and the flexible nonlinear periodization programs have emerged as very effective training models.