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Column Editor

Roundtable Discussion: Periodization of Training—Part 1

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summary

The concept of periodization is important for strength and conditioning professionals. This roundtable covers several aspects of periodization strategies.

The concept of periodization of training has been a topic of discussion and debate amongst athletes, coaches, and sport scientists for many decades. Large volumes of research have been done on the concept and its relationship to peak performance of athletes. In 1986, the National Strength and Conditioning Association (NSCA) brought together a group of strength and conditioning professionals to discuss the concept of periodization from a practical and scientific perspective in the pages of the NSCA Journal. The purpose of this current roundtable discussion is to revisit the topic of periodization with some of the original participants and add some of the latest scientific and practical applications of this training method.

Question 1: How Would you define the Concept of Periodization, Macrocycle, Mesocycle, Microcycle, Transition Phase, Volume, Intensity, Restoration, Frequency, Peaking, Overtraining, and Overreaching?

Kraemer: First, one must realize that with the progress in the study and use of periodization of resistance training since our last roundtable in 1986, the operational definitions have been pushed in many directions of which one can argue and debate, but this provides the intellectual perspectives to work with when using this concept. I have had the opportunity to hear so many different versions and work with a host of different periodization models from practice to laboratory; I am amazed at how far it has all come. The concept of periodization is what is most fascinating to me, and so many fine coaches and sport scientists are making headway into its understanding. Ultimately, periodization of training is mediated by the need for variation in the training stimuli (22).

One is also dramatically challenged by the need for "individualization" based on physiological status and predisposition and individual training goals to meet sport demands (3, 4). So, although the answers to these questions will have many different permutations and seemingly differences in various opinions, the basis for periodization is the need for program variation and programmed rest to keep the stimulus effective as one works toward his or her genetic predisposition for a given physiological or performance variable.

Many of the terms used are from the former Soviet Union and Eastern European countries in origin, as I remember reading about them in 1973 from blue mimeographed sheets sent out by Carl Miller with U.S. Weightlifting at the time (22, 23). Over time, American lifters, coaches, and scientists adapted the concepts and the terms so that many "hybrids" of the periodization concept and terms exist and continue to evolve today (3). This shows the level of utility and creative use of this important concept of training theory. So, it is important that each program carefully define what is meant by each of the terms so that better communication can be achieved when speaking about periodized training programs, as it is not a single entity anymore.

Despite the many different versions of periodization we have used, we essentially have "periodization" as a concept that can be defined by programmed variation in the training stimuli with the use of planned rest periods to augment recovery and restoration of an athlete's potential (16). Again, the key factor to optimal gains going toward one's genetic potential is "variation" in the exercise stimulus with systematic rest programmed into the equation. How that variation is achieved and used is the topic of a wide variety of different training goals and must also be individualized for each athlete and sport to achieve optimal success in his or her sport. Even in the model I used in a later question, the basic form is just the template from which to work. We have tried to stick with the classic terms and have limited excessive term creation, as the need has not been there for our applications in sport and in the laboratory. So, in classic terms of periodization theory, the macrocyle is the longest duration of the training cycle; typically a year is used for most situations, but some international programs have used a 4-year duration to coincide with peaking for the Olympic Games. The mesocycle is the next cycle duration further defining the amount of variation during the macrocycle. Prior work has shown that more mesocycles allow for greater training gains in physiological adaptation and performance, and thus many have used a 3-month mesocycle allowing 4 to be cycled in a year. The microcycle is the next and probably most important phase of training where changes in the acute program variables are prescribed to define each mesocycle and provide change and variation over time. The microcycle is typically about 2 weeks in duration, and this allows for variation to be carefully customized. My laboratory definition of intensity has been related to the resistance used for the exercise of which some call "load". We prescribe this typically in training repetition maximum (RM) ranges for most exercises (e.g., 3 to 5RM, 8 to 10RM) where the athlete does not have to go necessarily to failure on every set because of compression stress, but he or she should not be able to volitionally lift more repetitions in a set than the training range prescribed or then must alter the resistance on the next set up or down based on perception. Historically we have found that athletes can easily understand and pick the resistance to achieve this 3-repetition range resistance goal by trail and error. This approach reduces the need for multiple 1RM testing in every lift, which is administratively impossible. For structural lifts (e.g., cleans, hang cleans, etc) we use a combination of percentages of their 1RM for a given number of repetitions in a set. This is especially important for certain resistances used for power training but even when we are associating percentage and load failure in whole body lifts such as a power clean. On power training, with emerging research data in our laboratory and along with those of Robert U. Newton's laboratory, we have found that power exercises need to focus on "quality" of each repetition for maximal power or velocity of movement, and with the use of more sophisticated monitoring instrumentation and equipment we have found that this occurs in sets no longer than 6 repetitions, and that many of the repetitions do not hit critical cutoff levels needed for the quality training (unpublished data, 18, 24). Therefore, many athletes are not ready for high-quality power training because of many factors related to the fatigue state of the athlete (e.g., sport practice demands, other supplemental training, order problems in a workout design). Restoration is related to the need for rest and recovery over a training cycle. This is achieved with frequency of lifting, lower volumes of exercise, absolute rest, active rest, and strict attention to restoration techniques when needed (e.g., sleep, massage, hydrotherapy, etc). Frequency is the number of times per week that we lift. Peaking is related to a composite aggregation of all conditioning stimuli and sports practice that result in optimal or record performance in the sport for the athlete at a specific point in time. The peaking phase in a resistance-training program is the contributing factor to total conditioning for optimizing a performance at a specific point in time. Overreaching (OR) is where one increases the training stimuli in order to create a decrease in performance but one that has a "supercompensation" response or a rebound with increased performance at some point in time after the OR phase is completed (16, 25). Typically this would occur in the following 1 to 2 weeks. In our recent work, we have discovered that a training rebound program was possible after a high-volume phase (25). In this study, before initiation of the 4-week OR program, each participant underwent 4 weeks of base resistance training. This ensured that each subject began the study in a trained state. Base training consisted of 5 exercises per workout (squat, bench press, lat pull-down, leg press, and shoulder press) for 3 sets of 8 to 10 repetitions with 1 to 3 minutes of rest in between sets performed for 2 days per week. See Table 1 for the OR protocol used in the study. Multiple-set, periodized resistance training was performed on 4 consecutive days with a total-body program. Because of time limitation constraints with the subjects, the OR program utilized training each muscle group on consecutive days, thereby limiting recovery. The first 2 weeks consisted of a higher volume, moderate intensity of resistance exercise, whereas the last 2 weeks consisted of a higher intensity with a lower volume of resistance exercise. All sets were performed with RM loads such that all sets were performed either to or near muscular exhaustion. When each

Table 1
Resistance Overreaching Training Program Used in Study (26)

Week 1		
Monday, Wednesday	**Tuesday, Thursday**	**Friday**
Back squat 3 × 10–12*	Leg press 3 × 10–12*	1RM squat
Bench press 3 × 10–12*	Incline bench press 3 × 10–12*	1RM bench press
Lat pull-down 3 × 10–12**	Bent-over row 3 × 10–12**	
Lunge 3 × 10–12**	Stiff-leg deadlift 3 × 10–12**	
Seated shoulder press 3 × 10–12**	Upright row 3 × 10–12**	
Dumbbell curl 3 × 10–12**	Barbell curl 3 × 10–12**	
Lying triceps extension 3 × 10–12**	Dips 3 × 10–12**	
Leg raise 3 × 20***	Sit-ups 3 × 20***	
Week 2		
Monday, Wednesday	**Tuesday, Thursday**	**Friday**
Back squat 3 × 8–10*	Leg press 3 × 8–10*	1RM squat
Bench press 3 × 8–10*	Incline bench press 3 × 8–10*	1RM bench press
Lat pull-down 3 × 8–10**	Bent-over row 3 × 8–10**	Jump squats
Lunge 3 × 8–10**	Stiff-leg deadlift 3 × 8–10**	Ballistic bench press
Seated shoulder press 3 × 8–10**	Upright row 3 × 8–10**	
Dumbbell curl 3 × 8–10**	Barbell curl 3 × 8–10**	
Lying triceps extension 3 × 8–10**	Dips 3 × 8–10**	
Leg raise 3 × 20***	Sit-ups 3 × 20***	
Week 3		
Monday, Wednesday	**Tuesday, Thursday**	**Friday**
Back squat 5 × 5*	Leg press 5 × 5*	1RM squat
Bench press 5 × 5*	Incline bench press 5 × 5*	1RM bench press
Deadlift 5 × 5**	High pull 5 × 5**	
Lat pull-down 5 × 5**	Bent-over row 5 × 5**	
Seated shoulder press 5 × 5**	Close-grip bench press 5 × 5**	
Week 4		
Monday, Wednesday	**Tuesday, Thursday**	**Friday**
Back squat 5 × 3*	Leg press 5 × 3*	1RM squat
Bench press 5 × 3*	Incline bench press 5 × 3*	1RM bench press
Deadlift 5 × 3**	High pull 5 × 3**	Jump squats
Lat pull-down 5 × 3**	Bent-over row 5 × 3**	Ballistic bench press
Seated shoulder press 5 × 3**	Close-grip bench press 5 × 3**	

Note: * indicates 3 minutes of rest between sets; **, 2 minutes of rest between sets; ***, 1 minute of rest between sets; RM, repetition maximum.

subject was able to complete the desired number of repetitions with the current load, weight was added to subsequent sets or during the next workout. All workouts were supervised by a certified strength and conditioning specialist who also monitored the training loads. After the 4-week experimental period, each participant underwent a 2-week reduced-volume and -frequency resistance-training phase. The program used during this phase was identical to the base resistance-training program used before initiation of the 4-week OR protocol (i.e., 5 exercises per workout, 8 to 10 repetitions, and 2 days per week). Our conclusion was that the initial high-volume, moderate-intensity phase of OR followed by a higher intensity, moderate-volume phase appears to be very effective for enhancing a rebound in muscle strength in resistance-trained men (25). In addition, branch chain amino acids were also helpful in alleviat-

ing performance decrements in the alarm phase as well. Thus, training can be composited in different cycles to create the needed effect for a specific point in time and periodized training in which cycles used for OR are a natural part of this training concept and technology.
This might be thought of as true OR because of its positive performance outcome. Acute overtraining (OT) might be defined by the lack of this rebound training effect. Real OT is a chronic syndrome not easily observed and often confused with acute OT where performance is not restored within a few weeks of recovery. Thus, true OT is a long-term chronic decrease in performance capabilities that is a threat to an athlete's career.

O'Bryant:

- **Periodization** may be defined as a cyclical approach to training where periodic changes in training parameters (volume, intensity, loading, exercise selection, etc) are planned in order for the athlete to achieve optimal performance at the appropriate time.
- **Macrocycle** is generally thought to be a yearlong program typically beginning with high-volume, low-intensity exercise of the preparatory phase and ending with low-volume, high-intensity exercise of the peaking phase. However, some Olympic athletes are known to make use of more long-range planning characterized by a 4- to 8-year cycle with a peak in performance during a specific Olympic year.
- **Mesocycles** are shorter cyclical divisions within a macrocycle usually lasting only a few months.
- **Microcycles** are usually very short, lasting only a few weeks with slight to moderate variations in training on a weekly or daily basis.
- **Transition phase,** sometimes termed "active rest," provides a shift in training emphasis. Some have used this to recover from end-of-season stress where the athlete trains at a recreational level before preparation of the next competitive cycle. Others (6) have also used this phase (termed first transition) to link very high-volume, low-intensity training to very high-intensity, low-volume training.
- **Volume** is the total work performed (per exercise, session, week, month, etc). Weight-training volume can be estimated per exercise by volume load (repetitions multiplied by weight). Because of the cumulative effect, volume of training can be a potent precursor to physiological stress.
- **Intensity** is the quality of effort during training or power output (force multiplied by velocity). A qualitative measure of weight training can be estimated by the average weight being used and can be expressed as absolute (amount of weight lifted) or relative (percentage of maximum for an exercise). Speed of movement can be a determining factor when similar weights and repetitions are compared.
- **Restoration** is necessary because the physiological and psychological stress of training can lower work capacity. Proper rest and recuperation can renew the athlete's abilities to train. This can occur acutely (set-to-set) or over time (work session-to-session). Structured restoration can provide for training-induced recovery and supercompensation for increased rates of improvement in performance and higher levels of functional capacity.
- **Frequency** is the number of training sessions per day, week, etc.
- **Peaking** is maximizing performance at the appropriate time. In most sports (football, basketball, track, etc), a "true" peak is generally reserved for end-of-season championships and may last only about 3 weeks. Smaller peaks with shorter durations can also be planned for selective in-season competitions. The design of periodized training programs should consider the frequency, timing, and duration of peaking to optimize overall performance.
- **OT,** in general, may be defined as a plateauing or a decrease in performance resulting from the inability to tolerate or adapt to the training load. More specifically, there can be OT from "monotonous training programs" caused by consistent, unvarying use of the same type of training exercise. Another cause of OT is "chronic overload," or when overwork is sustained too long or repeated too frequently and the athlete can no longer adapt in a positive way. Recovery from this type of OT can require several weeks if not months (3).
- **OR** is a type of periodization where short-term (1 to 2 weeks) increases in volume or intensity are followed by a return to normal training. This brief phase can result in a delayed performance increase approximately 2 to 5 weeks after return to normal training (2, 5).

Pendlay:

- **Macrocycle** is a training period containing at least 1 preparatory, 1 competitive, and 1 transition mesocycle. It can be as short as 2 or 3 months but is not usually longer than 1 year.
- **Mesocycle** is a period within a macrocycle where a specific goal is pursued. It usually lasts 1 or 2 months but can be shorter or longer.
- **Microcycle** is a division of the mesocycle, which usually lasts 1 week. Dividing the mesocycle into several microcycles formalizes the process of varying the training stress within the mesocycle.
- **Transition phase** is a period where the athlete recuperates after stressful competition or training to be able to respond optimally to further training. This phase is most often thought of as a period of active rest after competition and before a subsequent preparatory period.
- **Volume** is the amount of work done within a time period such as 1 training day, a microcycle, or a mesocycle.

- **Intensity** is the difficulty of the training done relative to the maximum that the athlete is capable of.
- **Restoration** is the process of returning to normal or elevated functional capacity after training-induced fatigue.
- **Frequency** is how often a training stimulus is applied.
- **Peaking** is attempting to achieve maximum performance at a specific time, usually a major competition.
- **OT** is an imbalance between the training means and the recuperative ability of the athlete, resulting in a significant and long-term decrease in performance.
- **OR** is an imbalance between the training means and the recuperative abilities of the athlete, resulting in a short-term decrease in performance, lasting from 2 to 3 days to 2 to 3 weeks.

Plisk:

- **Periodization** is the planned distribution or variation in training means (content) and methods (load) on a cyclic basis. Macro-, meso-, and microcycles are the long-, intermediate-, and short-term units, respectively, that periodized training programs are structured into.
- **Volume** refers to training quantity, usually expressed in terms of repetitions and sets performed.
- **Intensity** refers to training quality, usually expressed in terms of impulse or power output during task execution. In practice, because of the fluctuating emphasis on these factors (volume and intensity), the concept of volume-load (mass lifted multiplied by repetitions performed) is more useful as an indicator of training stress than either one independently.
- **Frequency** is an indicator of training density over a given period and is therefore associated with other (volume) parameters.
- **Restoration** is a multi-pronged strategy to enhance an athlete's recovery from—and adaptation to—training. It should include rational program design, nutritional strategies, sleep, and application of therapeutic and regenerative techniques by a sports medicine professional.
- **Peaking** is one of the basic goals of periodized training: to exploit complementary training effects and minimize fatigue at optimal times. This is usually achieved by systematically reducing volume loads at the end of a mesocycle through tactics such as restitution microcycles or other "tapering" methods. This term is often used as a verb as well (e.g., to describe these strategies).
- **OR** is an advanced training strategy where volume loads are increased for 2 to 3 weeks and then reduced to normal levels to enhance adaptation and performance 2 to 5 weeks later by virtue of a "rebound" (supercompensation) effect. It requires careful planning and understanding of cumulative and delayed training effects. OT is a maladaptation syndrome resulting when OR-type workloads are applied inappropriately, for example, over prolonged periods or without adequate recovery or regard for the additive effects of other stressors. Long-term performance decrements and fatigue seem to be the universal indicators of OT and may or may not be accompanied by other symptoms.

Stone: Periodization as a term was apparently coined around the turn of the 20th century and referred to the photo periods of the sun; several coaches and sports scientists of the day noted that athletes usually were able to train and perform better during the summer months when days were longer, warmer, etc. Later, it was also believed that more fresh vegetables and produce were available during the summer and early autumn, and this influenced performance. During the 1920s and 1930s, periodization became more of a term applied to training methods. One of the first sports scientists to attempt to systematically study the concept of periodization in relation to sports training was L. Nadori of Hungary in the 1940s and 1950s. Apparently, Nadori was a large part of Hungary's success in sports during the 1950s and early 1960s (personal communication, I. Balyi and J. Tihanyi). Later, Yakolev, Matveyev, Verkoshansky, Bondurchuk, Tchiene, Haare, and many other sports scientists worked to refine the concept. To my knowledge, it was not until the 1960s and 1970s that Americans began to seriously consider periodization as a concept, much of it was discussed in *Track News* and *Track Technique* in articles written or edited by Fred Wilt and Vern Gambetta. During the late 1970s, my colleagues and I began a series of studies, which have continued until today. These studies primarily have dealt with the use of the periodization concept in a strength-power training paradigm. Harold O'Bryant is a pioneer in these early strength-power studies, and his dissertation should be a must read for anyone interested in the concept. Although the concept of periodization has a long history, the basic focus in the development of the concept has been achieving appropriate variation, which includes alterations in training variables as well as "built in" recovery and restoration. Thus, conceptually, periodization is directly concerned with the "training process." Today, periodization can be defined as a logical phasic method of varying training volume, intensity factors, and exercises in order to optimize training progress. Thus, periodization is a nonlinear method for planning the training process.

The primary goals of periodization are (a) the avoidance of OT and (b) performing at peak or optimum levels at the right time (8). Although the periodization concept is most associated with climactic sports (i.e., peaking), this planning process can be modified and adapted for seasonal sports (14, 15). The time frame for periodization can be divided into several different levels—an important consideration is that each level can provide additional variation (14, 15):

- **Period** is the total length of the training plans; for example, it can be a 4-year cycle for Olympic sports.
- **Macrocycle** (**long-length cycle**) typically the macrocycle lasts about a year. Over this time period, the macrocycle typically provides for initial high-volume training (preparation) moving to high-intensity technique-oriented training.
- **Mesocycle** (**middle-length cycle**), typically 2 to 3 months, can mimic a macrocycle in terms of volume and intensity alterations, or it can be primarily devoted to 1 phase (i.e., general preparation [GP], special preparation [SP], competition).
- **Microcycle** (**short length**), typically 1 week, can vary from week to week and day to day.
- **Summated microcycles** are blocks of microcycles (usually 3 to 6 weeks) in which each block presents a specific pattern of volume and intensity loading. The blocks can then be repeated throughout a mesocycle such that specific stimuli are "re-presented" in a cyclical fashion. Generally, a block consists of 4 weeks. A typical block, used for enhancing strength, would be one in which intensity and typically volume load (i.e., overload) are increased for 3 weeks followed by an "unload" week creating a 3/1 block (15, 20); the block can then be repeated again offering a similar stimulus (Figure 1). In the example (Figure 1), sets and repetitions are held constant—volume load increases or decreases as a result of loading (training intensity [TI]) alterations. Note in Figure 1 that as the volume load is increased across the first 3 weeks that accumulated fatigue can also increase, thus the need for an unload week (week 4). This type of summated microcycle system is not optimal for power or speed development because of the persistent increase in accumulated fatigue across the first 3 weeks of each block. A summated microcycle system in which the greatest volume load is placed in the first week, followed by decreases in volume load and increases in exercise intensity (EI) (i.e., power output) from weeks 2 to 4 allowing fatigue to dissipate, favors development of power and speed.

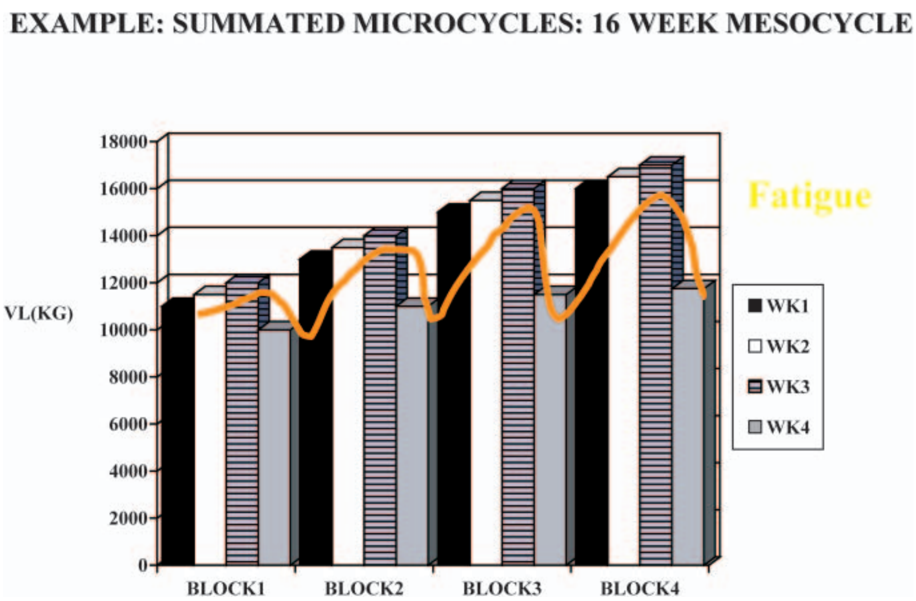

Figure 1. Paradigm emphasizing strength gains. VL = volume load.

- **Peaking** is a specific phase of a climactic sport usually at the end of a mesocycle devoted to bring performance up to maximum levels. This is usually achieved by lowering the volume of training and raising either TI or EI in line with the performance requirements.
- **Frequency** is how often a specific stimulus is applied (per day, per week, etc).
- **Intensity** is related to a work rate or power output. From a coaching standpoint, here are 2 types of intensity which are important in this context (14, 15):
  (a) **TI** is equal to the average load (volume load and repetitions) and is an estimate of the work rate across a training session. It may be calculated as an average daily, weekly, monthly, etc, function. TI may also be expressed in relation to maximum ability; the relative intensity is expressed as a percentage of a 1RM for a specific exercise or a group of related exercises.
  (b) **EI** is the actual power output of an exercise. EI can be expressed as the average or peak power output achieved during a single movement or the average power over a series (set) of movements.
- **OT** is a maladaptation to training as a result of the accumulation of stressors (either induced by the additive effect of the physical and emotional stress of the training itself or the additive effect of accumulative daily stressors). The maladaptation can manifest itself as a plateau or reduction in performance potentially accompanied by a number of stress markers (4). OT may manifest as sympathetic characteristics (most often occurring among strength-power athletes) or parasympathetic characteristics (observed in some endurance athletes or as a result of exhaustion after prolonged sympathetic manifestation). Sympathetic OT is characterized by chronic fatigue and many other signs and symptoms mimicking stimulation of the sympathetic nervous system. Parasympathetic OT is characterized by phlegmatic behavior, the inability to

"rise to the occasion," and other signs and symptoms mimicking parasympathetic stimulation. OT is a serious condition and requires prolonged recovery. Associated with OT is monotonous training (MT) in which performance may plateau or decline somewhat without fatigue or overt OT symptoms. MT may be a result of simply making exactly the same movements repeatedly, resulting in lack of necessary variation for the nervous system. MT can be easily remedied by making changes in the movement pattern (i.e., exercise selection).

- **OR** is a condition produced most often by sudden increases in training volume. OR may produce some of the signs and symptoms of OT but not as severe. A reduction in training volume or intensity and return to normal training can produce an increased performance several weeks after the OR. Sometimes a supercompensation effect will occur boosting performance to new levels. Thus, OR (12) can be planned (carefully) into the periodized program (usually 1 to 2 weeks of increased volume) and may result in a performance boost.

Question 2: What are the Various Phases of a Periodized Training Program? In Your Explanation, Please Define the Goals of the Individual Phases of a Periodized Training Program.

Kraemer: This is a complex question and one that is highly related to the type of periodized model that you use. We have written about this at length (3, 4, 16). In general, one talks about a number of phases, from the GP phase (where the athlete builds the necessary general fitness needed to move to a periodized training program) to the transition phases (for the training needed before another cycle) or the recovery phases (where rest is the most important factor in preventing OT, both from a psychological and physiological perspective). Dr Fleck and I have written about this in detail (3, 4). The American form or periodization most often thought of was essentially developed in 1981, when Stone and colleagues (28) in the United States developed a hypothetical model for strength and power sports of the more classic periodization program that had been used by Eastern European weightlifters. The model broke down a training program into 5 mesocycles. The resulting periodization program was characterized by initiating the training with a high volume of exercise (i.e., more sets and repetitions) and using low intensity (i.e., low resistance) as has been depicted in many citations over the years (28). During each of the following mesocycles, the volume of exercise is decreased, and the intensity or resistance is increased. In this model, the initial phase of training is termed the hypertrophy phase, characterized by high-volume and low-resistance exercise. The major goal of this phase is to increase toleration to resistance exercise and to stimulate initial needed increase muscle mass. The major goal of the strength and power phases is to bring about increases in maximal strength and power, respectively. The goal of the peaking phase is to peak strength and power for a particular competition. The decrease in volume helps compensate for the increasingly heavier resistances (increased intensity), which must be used to promote maximal strength and power increases. The active rest phase consists of either low-volume, low-intensity resistance training or some other light physical activity. The goal of this phase is to allow the body to recover from the previous training, both physically and psychologically. In fact, this aspect of periodized training may be the most important, as highly motivated athletes will many times not want to take the needed rest that their bodies require for optimal adaptations. By not planning for periods of rest and recovery within a training program, the possibility of staleness or OT is increased. The goal of the entire training cycle is to achieve the highest strength and power level possible in the time allowed for the whole training cycle and peak strength and power for a major competition. Time for the active rest mesocycle is then allowed, and the entire macrocycle is repeated. Periodization was originally used to peak for 1 major competition a year, such as the world championships. So, each of the mesocycles was 2 to 3 months long. The greater gains in strength and power are probably related to the basic concept of periodization in that variation in training is needed to achieve optimal gains, and multiple training cycles provide more variation in training.

O'Bryant: When looking at a periodized training program, we can break down the overall training into 4 components: (a) preparation, (b) transition 1, (c) competition, and (d) transition 2 (active rest).

- **Preparation.** Early preparation begins with an emphasis on general fitness with high-volume, low-intensity work. Additional preparation follows with more high-volume, low-intensity exercise but with movements that have somewhat higher specificity to the sport. The goal of this phase is to stimulate positive body composition changes (increase in lean body mass, etc) and improve short-term endurance and work capacity.
- **Transition 1.** This provides a shift to lower volume exercise while intensity progressively increases with both resistive (weight) and temporal (speed) loading. Exercise selection becomes even more biomechanically specific to the sport with an emphasis on development of strength and power in response to decreasing workloads.
- **Competition.** The objective here is to stabilize or improve technique while improving performance variables specific to the sport. Power and strength can be brought to a peak by more volume reductions coupled

with increases in intensity. Power athletes need more emphasis on speed of movement, reactive training (plyometrics), and technique work. A maintenance program can also be associated with this phase and is essential for sports with prolonged competitive seasons. The maintenance of reasonable levels of physiological conditioning requires sufficient volume, intensity, and frequency. This total work, in combination with sport skill practice, should be carefully balanced to avoid overwork and subsequent decrements in performance.

- **Transition 2 (active rest).** If hard training is attempted immediately after peaking or prolonged season, long-term progress will be diminished. Active rest is characterized by low workloads and intensities and may involve recreational activity with complementary movement patterns and motor skills.
- **Note** that the duration of each phase is dependant upon the athlete's maturity, level of conditioning, sport, and timing relative to season.

Pendlay: There are 3 main phases of a periodized training program: preparatory, competitive, and transition. The goals of the preparatory phase should be to establish higher levels of basic physical capacities such as strength and speed and to improve any weak points that were apparent during the last competition. The goal of the competitive phase should be to obtain maximum performance at the planned competition. To this end, training in the competition phase is generally more specific to the practiced sport, more intense, and of lesser volume than in the preparatory period. The goal of the transition phase is to maintain as much of the general conditioning as possible while allowing the athlete to rest; to recuperate from the previous competitive period, both physically and mentally; and to become ready to withstand the subsequent preparatory period. Training is usually of a different means than the main sport training and of a lower volume and intensity.

Plisk: The "phase" approach to periodization is just one of at least three strategies. In my opinion and experience, it is most applicable for novice athletes. I should qualify that by stating that such strategies may be the most valuable of all because of their broad applicability. There are many more novice athletes in the early stages of development (for whom advanced tactics are inappropriate) than there are elite athletes in later stages.

The phases associated with steplike Western periodization models are usually referred to as strength endurance, strength and power, peaking (maintenance), and active recovery (transition). Note that the term "strength endurance" is chosen instead of "hypertrophy," because it more accurately reflects the main objective of this period: increased work capacity. Body-composition changes, though important, are secondary. This strategy can be viable for novice athletes who are learning new movement techniques or are unaccustomed to high intensities. It is potentially problematic, however, when relatively flat workloads are prescribed over a period of several weeks. Consecutive weeks spent within such narrow workload ranges can effectively amount to less than 1 week of novel stimulus followed by 2 to 3 weeks of monotonic stress, increasing the likelihood of accommodation and stagnation problems. These shortcomings may be prevented by using zig-zag progressions where volume loads are varied within reasonable ranges.

Intermediate periodization strategies are characterized by greater levels of variation within—as well as between—respective cycles. Although a beginner's program may consist of simple progression on a macrocyclic basis, tactical decisions are now directed toward meso- and microcyclic variables (e.g., the degree of workload contrast between mesocycles, microcycles, or individual training sessions as well as within sessions). Summated microcycles are one such strategy (refer to Figure 1). They usually involve 4-week mesocycles with an extensive to intensive workload progression and a brief restitution period. Training-method distribution is the key difference from the basic approach described above. Specifically, a microcycle rather than mesocycle is allocated for strength endurance, strength and power, peaking, and recovery. This pattern of loading, where 3 weeks of increasing volume or intensity is followed by an unloading week and the progression is then repeated at higher intensities, allows complementary stimuli to be reintroduced in a regular cyclic fashion such that their effects do not decay significantly. Discretion should be used with this approach because the greatest workloads occur in week 3, by which time cumulative fatigue may hinder speed-strength expression, hence the need for unloading in week 4 to reduce OT potential and promote adaptation.

A summated microcycles strategy seems to have dual benefits: As a form of intramesocycle variation, they increase the probability of converging training effects while minimizing the likelihood of overstress or accommodation and involution problems. Furthermore, they add an aspect of intermesocycle contrast that can be advantageous as an adaptive stimulus. Other strategies (e.g., planned OR) may be more effective for advanced athletes.

Advanced periodization strategies are characterized by extensive, systematic variation in both content and workload at multiple levels of the program (i.e., between and within respective micro-, meso-, and macrocycles). "Conjugate sequence" training is one such system. It is an intermesocycle variation strategy that involves periods of accumulation or intentional OR followed by restitution

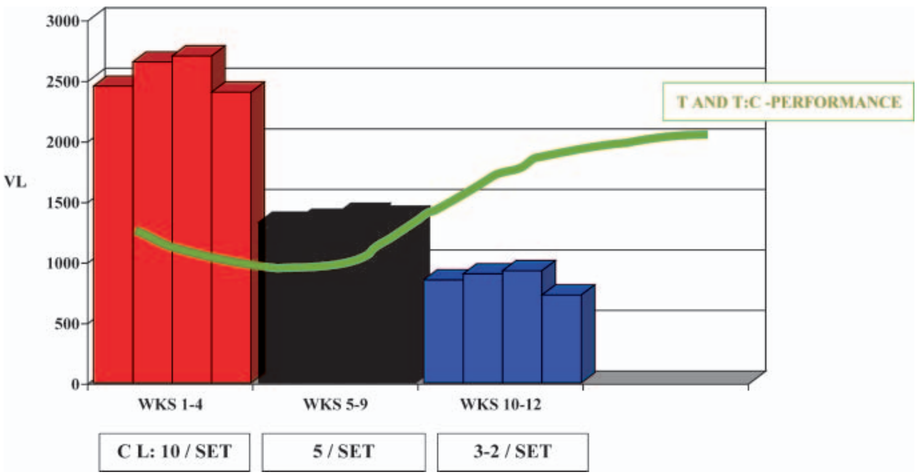

Figure 2. Model I (1977). CL = concentrated loading; T = testosterone; T:C = testosterone: cortisol ratio.

during which supernormal responses can be exploited (refer to Figures 2 and 3). This is achieved through a series of "concentrated blocks" that are usually 4 weeks in duration. During the first block, the athlete performs high-volume loads of work with one primary emphasis (e.g., strength and power) and minimal-volume loads—presumably maintenance type—allocated to other abilities. The objective is to saturate the system with one type of stress over a period of several weeks, during which temporary decrements in certain performance capabilities can be expected because of residual fatigue. Emphasis is essentially reversed during the subsequent restitution block: Strength-training volume load is markedly reduced, whereas the volume load of work allocated to another quality (e.g., speed and technique) is increased moderately. If implemented skillfully, the athlete's performance capabilities rebound by virtue of a delayed training-effect phenomenon, allowing new levels of movement speed and technical execution to be achieved. The athlete can then proceed to the next sequence of blocks with progressively stronger stimuli.

In contrast to the concurrent approach used in many basic and intermediate programs, sequenced training is a significant departure (i.e., developing various qualities over successive mesocycles such that one potentiates another while minimizing residual fatigue and compatibility problems). Proponents of this strategy cite several advantages: First, it provides the potent training stressors needed to bring advanced athletes to a new functional state that otherwise cannot be achieved through traditional methods. Second, it circumvents the cumulative fatigue problems associated with parallel or concurrent training of multiple qualities. Third, it allows long-term work volumes to be reduced. This comes with a price over the short term, however. During each accumulation block, athletes must be able to tolerate high-volume loads for several consecutive weeks. This can be particularly problematic without the systematic application of restorative and regenerative measures.

In all cases, convergence of training effects, management of fatigue, and prevention of stagnation or OT should be the bottom-line goals of periodized training. Simply put, the respective phases should potentiate the effects of others, in much the same way that sport coaches use a play or scheme to "set up" another. The consensus arising from the literature is to organize training programs into 4-week periods, which seem to be an optimal biological window for integrating responses. These can be structured in at least two different ways: as a mesocycle to be subdivided into multiple microcycles and objectives (for basic and intermediate applications) or as a "block" with essentially 1 objective arranged as part of a series (for advanced applications).

In terms of long-term developmental objectives, here are some common analogies that seem to be useful:

- **Beginner or novice:** "train to train"; emphasis on GP.
- **Intermediate:** "train to compete"; balance of GP and SP.
- **Advanced:** "train to win"; emphasis on SP.

Stone: When considering a periodized training model, the typical phases would be:

- **GP:** This phase occurs when a high volume of less specialized work is performed. It typically lasts 1 to 3 months but may be repeated during a macrocycle; the purpose is to raise the levels of "fitness" specific to a sport. Often the GP or part of the GP is used as a unidirectional concentrated loading block. It should be noted that the GP phase is not necessarily general (i.e., exercises specificity) but rather less specific.
- **SP:** This is a relatively high-volume phase in which the exercises selection becomes more specific to the sport performance. As with the GP, this phase can be used to aid the athlete in raising work capacity but in a more specific manner.
- **Competition:** This is a lower volume, higher intensity phase associated with very specific exercise selections. The athlete can stabilize or improve technique while improving performance variables specific to the sport, for example, raising strength or power levels for sprinting or basketball. A special aspect of the competition phase is peaking (for climatic sports), during which a taper allows sports perfor-

mance attributes to increase to peak levels (likely as a result of fitness versus fatigue phenomena).

The length of time spent in each phase depends upon the (a) level and age of the athlete, (b) previous training history, (c) type of sport, and (d) length of the period. It is important to understand that these phases can be manipulated in a manner to fit most sports situations, including seasonal sports.

Using these basic concepts, my colleagues and I developed several models for periodization programs dealing with strength-power training. The first of these models was developed and used with athletes in late 1977 and early 1978 by Harold O'Bryant, who describes this model (and others) in his doctoral dissertation, and a first paper was subsequently published (13) describing the very rudiments of this model on a mesocycle level (several weeks). This model was based on several factors, including arguments made by Tchinene, Haare, Matveyev, and Verkoshansky. Essentially (on a mesocycle level) there are 4 phases involved (Figure 2):

- **Concentrated loading (strength-endurance) phase.** This phase usually lasts 4 weeks. Originally we termed this a hypertrophy phase; however, the purpose as described then and now was to make positive alterations in body composition and, more importantly, to alter the athlete's high-intensity exercise endurance—essentially, to get the athlete into shape. We observed (as did Verkoshansky) that this phase resulted in the improvement of certain attributes (i.e., body composition and strength endurance). However, maximum strength, particularly power and speed, did not always improve and often decreased among power athletes. We further noted that after a few weeks of normal training, both maximum strength and particularly power and speed often increased markedly. This phase is largely unidirectional (mostly resistance training is performed) and is usually part of a GP.
- **Basic strength phase.** This phase usually lasts 4 to 8 weeks and is of moderate volume typically characterized by repetitions of 3 to 5 per set. The primary purpose of this phase was to raise maximum strength levels, particularly in complex multi-joint movements.
- **Strength-power phase.** This phase usually lasts 4 weeks. Volume is lowered and is typically characterized by 1 to 3 repetitions per set. The types of exercises can become more power–speed oriented if power and speed are a primary goal. If the mesocycle ended just before an important contest, then a peaking phase or taper was added in which the volume was lowered and either the TI or the EI was raised in accordance with the demands of the sport. In theory, the peaking phase takes advantages of the fatigue-fitness relationship (see question 3).
- **Active rest.** This phase usually lasts 1 week and allows the athlete to recover physiologically and psychologically. This can be low-volume, moderate-intensity resistance training; some other activity or a combination.

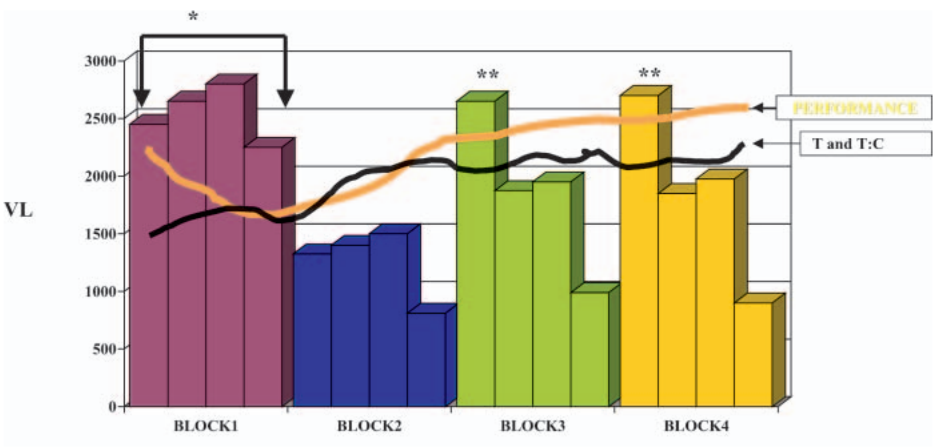

Figure 3. Model 3 (1995). * = 4 week concentrated loading phase; ** = 1 week overreaching phase; T = testosterone; T:C = testosterone: cortisol ratio.

Thus, this model starts with a high volume and moves to a lower volume in a stepwise fashion (not linear) offsetting increases in TI. Although day-to-day variation is not as necessary with absolute beginners, the use of this model with athletes has always included heavy and light days, thus volume load "undulates" across a week and throughout the entire mesocycle (7). It is still my opinion that this model is the superior training method for novice strength-power athletes. We used this basic model in the development of several national and international level athletes, including Joe Majacyzk (20-m + shotput) and Mike Davis (silver-medal winner in the 1983 Pan Games, Olympic Games 1984, 100-kg weightlifting). Kyle Pierce (U.S. Weightlifting Development Center, Louisiana State University, Shreveport) still uses this basic model in the development of young weightlifters. Shortly after this model was developed (1977 and 1978), it became quite apparent to us that greater variation in training was necessary for advanced athletes, particularly strength-power athletes.

Between 1995 and 1997, we developed a model of training that we still use with advanced athletes today. This model uses the concepts of concentrated loading and planned OR (Figure 3). Briefly, planned OR deals with sudden and marked increases in loading. Typically this loading lasts one week and may be termed concentrated loading. Power and speed are often decreased significantly during periods of concentrated loading. However, after a few weeks of normal training performance can significantly rebound. If a taper is added to the end of the mesocycle, then performance may increase even further. This model is divided into several 4-week blocks (summated microcycles). The first block begins with a concentrated load (sets of 10), again to ensure the athlete is in shape to train. The athlete then returns to normal training (4 weeks) with a strength-emphasis block. In the next 2 blocks, a planned OR paradigm is used. The concept is to periodically try to boost performance through supercompensation (stimulus, fatigue, recovery, adaptation) through the use of the OR phase and return to normal training and a taper (12). In consideration of the type of sport, exercise selection can vary through each block depending upon the parameters of the sport (i.e., strength emphasis or power emphasis). We have used variations of this method in the training of several national and international sprinters, jumpers, throwers, and weightlifters, both in the United States and Great Britain. For example, Meg Stone used a variation of this method in developing the strength-power training program for Jonathan Edwards (gold-medal winner, triple jump) leading up to the 2000 Sydney Olympic Games.

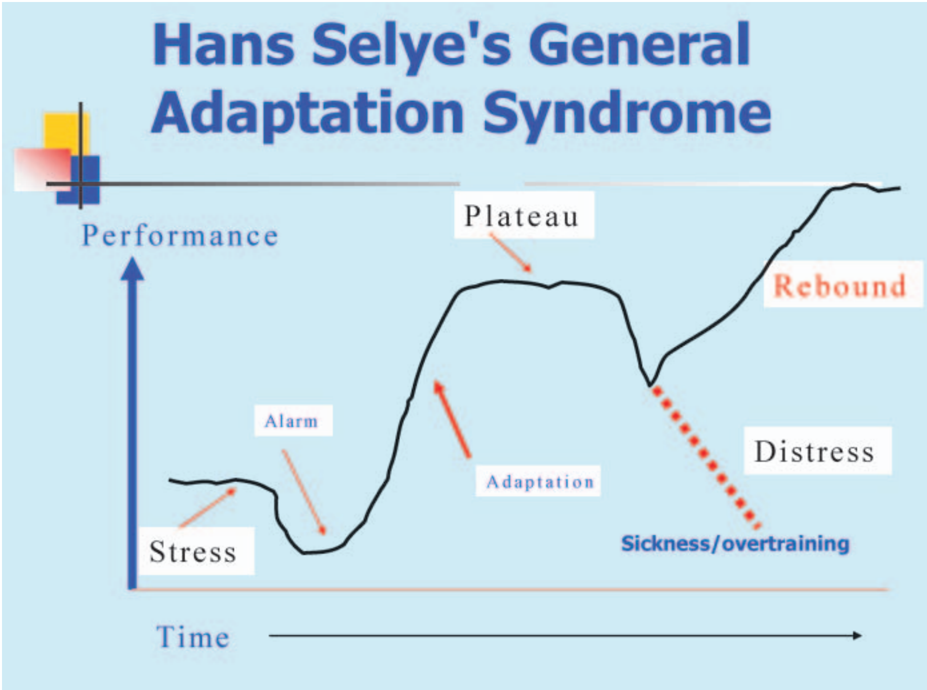

Figure 4. The classic model for periodization using concepts of the Selye's General Adaptation Syndrome applied to training technology and theory. The exercise stress is introduced and is followed by an alarm reaction, a period of adaptation, a performance plateau, and then a need for rest before the next cycle of training starting at a higher level of function.

Question 3: What is the Physiological Basis Behind the Concept of Periodization?

Kraemer: In general, the physiological basis for periodization historically appears to be based on the classic findings of Hans Selye, a Canadian endocrinologist who studied various types of biological stressors to organisms and coined the concept of the "general adaptation syndrome" (GAS; see Figure 4) (26, 27). Ultimately, subsequent studies testing his theory have shown that stress is not general but very specific in its pattern and responses. These new findings further support the training principle of specificity, indicating that stimuli are not a general phenomenon either. Nevertheless, Selye's GAS provided a theoretical framework for the need of variation in training and, more importantly, the need for the withdrawal of the stressor at some point in time to allow the organism to survive. This was an important concept in the evolution of the training principle of "progressive overload" developed in part by the work of Thomas DeLorme (who just recently passed away at age of 85) during the post–World War II years, focusing on the physical rehabilitation of wounded soldiers (2). Thus, GAS has been written about extensively and is in almost every textbook on resistance training. It starts with the introduction of the stimulus that is novel, and this results in a reduction in performance during what has been termed the alarm reaction. If the organism survives, a period of adaptation to the stimulus follows for a duration, leading to a plateau effect. One has a limited time on this plateau of adaptation to the timulus if it is above the prestimuli level. Then, if the stimulus is not removed or reduced dramatically, a dramatic fall-off can occur, caused by the organism's inability to continue to tolerate the level of stress experienced. In human terms, this means that if the stress of training is not altered or reduced, or if active rest is not allowed, then the athlete can become sick, injured, experience acute OT, or worse. This was based on the potential biological backdrop for the concept of periodization in that there is an alarm phase followed by an adaptation to a stimulus, followed by a plateau of performance and then staleness or sickness if rest is not provided. The programmed rest phase then allows one to recover and get ready to undertake a new cycle of training but from a higher level of adaptation than in the previous cycle. A new cycle is started, and the same series of events unfold, but ultimately higher and higher plateaus of performance and adaptation are achieved leading up to one's genetic potential for a particular variable. Key to this principle were again a number of factors, including a certain period of adaptation (e.g., 6 to 8 weeks), a plateau (e.g., 1 to 2 weeks), and exhaustion or death of the organism if the stimulus was not removed because of the inability to continue to adapt to the stress. Thus, the withdrawal of the stimulus was needed and to provide relief. The concept of planned cycles with rest and variation in the exercise-training stimulus are key to the concept of periodization (29, 31).

In addition, we have found that the extension of "size principle" of motor-unit recruitment is also important to understanding the biology of periodization (4). The basis of this is related to the variation of loading resulting in different recruitment patterns of muscle. Not all motor units are used for every "set, rep, resistance" in a workout. The variation in the recruitment of motor units is vital for providing variation in the stimulus to the muscle-mass recruitment. Thus, on a light day, one will not be recruiting the same motor units as on a heavy day, thereby allowing such higher motor units active recovery. Although this relates to the physiological disposition of the individual, the concept applies. In Figure 5 you can see a graphic representation of the size principle as applied to recruitment of motor units. Each circle represents a group of muscle fibers recruited by a motor neuron. On the basis of size principle, many sizing factors can come into play: the size of the electrical threshold, the size of the motor unit, the size of the fibers, etc. In general, motor units are small and large, and as one ramps up to maximal force production, more and more motor units are recruited to meet the demands of the external load. In addition, specialized patterns of motor units may mediate high-power outputs that require both force and velocity adjustments. There are even cases of exception to size principle to augment the speed of recruitment of the high-threshold motor units by inhibition of the lower threshold motor units. Variation in the resistances used, the volume of exercise, and the metabolic demands will create different patterns of motor unit recruitment supporting the concept of variation in training. Higher motor units do not like to be repeatedly activated, leading to various types of motor unit recruitment patterns in lower threshold motor units (e.g., asynchronous recruitment patterns). Not all motor units have all the ranges of capability, as this total spectrum unit portrayed in Figure 5. For example, higher threshold motor units may be lost with aging. With some athletes such as cross-country runners, more type 1 motor units may exist in a locomotion muscle, and only a very small percentage of type 2 motor units would be present if at all; thus, speed and power activities are accomplished by some level of use of higher threshold type 1 motor units.

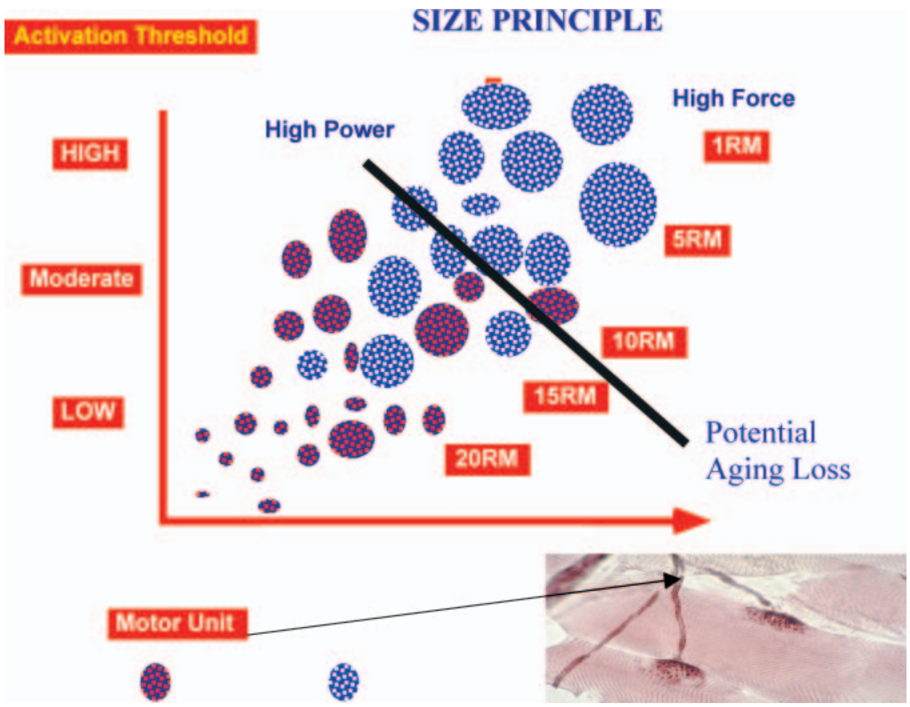

Figure 5. A generic total spectrum is represented in this graphic representation of a theoretical motor unit that has a full array of motor units. RM=repetition maximum.

In other words, each motor unit has a given number of muscle fibers associated with it. This ranges from slow motor units with low thresholds and few fibers at the lower end of a spectrum to high-threshold motor units with many large type 2 fibers at the upper end of the spectrum and mixes in between. These fibers contain either type 1 or type 2 muscle fibers and are of various sizes and recruitment thresholds. Recruitment starts with the lower motor units and goes to higher and higher electrochemical threshold as motor units are recruited to meet the demands. Not all individuals have the same number of motor units, owing to the differences in force and power production capabilities we see in different muscles and human beings. With periodization, the goals of using different motor unit recruitment patterns is vital, as muscle-mass recruited and total work done has dramatic implications on a host of physiological support systems and adaptations that take place outside the muscle tissue itself. Such recruitment patterns dictate cardiovascular stress, endocrine responses, immune responses and repair, and connective tissue responses, to mention a few major systems. Remember, all physiological responses to resistance training start with the workout resistances and muscle mass used to perform the exercises (16). This leads to a very specific pattern of physiological response to a workout and training program. Variation is a key to the progression of resistance training.

Finally, periodization is the needed concept, as it relates to the principle of training variation and further defines the principle and method of progressive overload with long-term training (13, 16).

O'Bryant:

- **Physiological fatigue can act as a stimulus.** When this stimulus is followed by adequate recovery, physiological adaptations occur (biochemical, cellular structure, etc) which may include increases in muscle hypertrophy, energy reserves, and other changes, both muscular and neurological. Repeated over time, the cumulative effect can lead to enhanced physical performance. However, inadequate recovery leads to accumulated fatigue and can be counterproductive. Periodized training is designed to properly manage fatigue and recovery to maximize the beneficial effects of supercompensation while reducing the potential for OT.
- **Sequenced training can lead to improved physical performance.** Progression from one type of training may enhance the benefits obtained from subsequent training of a different type. Training protocols that promote basic strength followed by protocols that focus more on power will tend to increase the potential for improvements in power. Likewise, periods of training that promote power followed by periods of training that emphasize speed of movement will tend to increase the potential for improvements in speed.

Pendlay: Hans Selye described the GAS as consisting of an alarm stage, a resistance-development stage, and an exhaustion stage (5). If the same training stimulus is presented again and again, it will eventually either fail to elicit an alarm or will lead to exhaustion. In a periodized program, training stress is varied over time to continue to reach the resistance-development stage but not to reach the exhaustion stage.

Plisk: Selye's GAS concept seems to be the prevailing theory upon which periodization is based. The fitness-fatigue model is another important theory with important implications for program planning and management. I will limit my comments to some practical considerations, as I am not as qualified to address these issues as are Drs Kraemer, O'Bryant, and Stone.

From a chronic programming standpoint, we should appreciate that the GAS becomes more of a specific adaptation syndrome as each athlete's development advances (in keeping with the said principle). In novices, however, basic or nonspecific training methods can yield relatively broad improvements in performance. This has important ramifications when interpreting the research because many studies involve previously untrained athletes, and thus results cannot be generalized to advanced populations (fortunately, the body of evidence examining intermediate and advanced subjects is steadily growing). It also means that training methods used by advanced athletes are not necessarily the best way for beginners to become advanced. Some coaches and athletes do not believe or understand that.

This issue has important implications when planning advanced training programs as well. It can be easy to get into a specificity trap with elite athletes by excluding many viable GP methods. In principle, it is true that such methods play a limited role for qualified athletes. In practice, however, we run the risk of monotony and stagnation problems if we do not prescribe enough stimulus variation. In my experience, this is where training tactics based on "acute after-effect" phenomena (e.g., postactivation potentiation) are most useful. Examples of these include combination and hybrid exercises, complex training, wave loading, and so on, where one type of stimulus is used to enhance impulse or power output in another. In this way, movements that are not mechanically specific to an athlete's sport can still be used to augment the effects of those that are.

Stone: There are several underlying mechanistic concepts and theories that can be discussed in this context.

- **Selye's GAS.** Although GAS was not originally created to deal directly with sports, many of its tenants do help explain some of the observed phenomena associated with physical training. Although we know now that the GAS does not explain all reactions to stress (reactions to stress are not necessarily that general), GAS can serve as a model to help understand the need for variation in sports training. This concept basically deals with the idea that stress (in small amounts) can cause beneficial adaptation but can also become accumulative, and that if total stressors become too great the normal adaptive systems no longer operate efficiently and breakdown eventually occurs. Thus, to survive and adapt, an organism needs periodic breaks for stressors. The breakdown process for athletes is believed to progress through various stages such as accumulative fatigue, OR, and OT, with each stage having more serious consequences and taking longer for recovery. Thus, relief (i.e., variation) from constant or overwhelming stress is paramount. Garhammer (5) has presented an excellent description of the adaptation of GAS to sports training.

- **Stimulus-fatigue-recovery-adaptation.** This mechanistic theory deals with the concept of supercompensation, which is basically an adaptation to an appropriate stimulus. Basically, an organism is exposed to a stimulus that, while causing fatigue, sets in motion underlying physiological mechanisms (i.e., biochemical, hormonal), which, during the recovery process, cause adaptations allowing the organisms to "perform" at a higher level. These potential supercompensations could include increases in energy stores, hypertrophy, neuromuscular adaptations, or hormonal alterations. These physiological adaptations would then lead to enhanced performance. This concept is not limited to a single exercise-stimulus response but may be viewed on a longer basis producing training adaptations. For example, Verkoshansky (17, 18) noted that a concentrated load of strength or strength-endurance training for several weeks could result in a diminished speed-strength (power) capability among track-and-field athletes. Upon returning to normal training, increased power performance can often be observed, sometimes beyond baseline values. Similar results have been observed among young weight-lifters after a planned high-volume OR phase (3, 12) and may be linked to alterations in anabolic and catabolic hormones.
- **Fitness-fatigue relationship.** According to this theory, sport preparedness is defined as the summation of 2 after-effects of training stress: fatigue and fitness (20). In contrast to the supercompensation theory based on a cause-and-effect relationship between these factors (i.e., adaptation), the fitness-fatigue model proposes that they have opposing and antagonistic effects. This has an important implication: Performance is optimized resulting from a training process that minimizes the fatigue responses to training and exercise stimuli while maximizing the fitness responses. It should also be noted that this theory is the basis of a taper effect.
- **Sequenced potentiation.** Associated with the concentrated loading theory is the concept of sequenced training and one training phase potentiating the subsequent phase. For example, Wilson et al. (19) demonstrated that among heavy weight-trained subjects with reasonable maximum strength levels, switching to high-power training (squats) improved a variety of performance variables beyond those of continued heavy weight training. Similar observations have been made among elite weightlifters (9) and American collegiate football players (6). This suggests that for increasing power and speed, a training and periodized/variation sequence emphasizing strength, power, and speed may produce superior results.

Question 4: Periodization is Often Suggested to Allow for the Avoidance of OT. What is the Mechanism Within the Periodized Training Model That Allows for the Avoidance of OT? How Should Training Variables be Altered in the Event that OT Does Occur?

Kraemer: With one of the contributors to this roundtable and a former member of my laboratory group, Andrew Fry and I have done many studies on acute OT in my laboratory over the years, and the key factor in these studies has been the use of complete rest to eliminate or reduce the impact of a performance decrement being observed (5–10, 19). Periodization plans rest periods that are vital for recovery and restoration of physiological mechanisms and body structures (e.g., muscle fibers). Another key is the variation in loading and intensity over time. We have found that if you provide complete days of rest even with very heavy lifting (multiple 1RMs) or even high-volume training, OT can be avoided (6). Others may have their impressions, but it is as simple to me as rest at the right time of the training cycle. one have written extensively on how one can make mistakes in program design by allowing the rate of progression to move up too quickly in its stress level (19). Beyond making dramatic mistakes in designing the workout protocol, rest is the key.

Again, operationally one can recover from acute OT that may not show a rebound in performance and might be termed staleness. But such staleness may well be the precursor to chronic OT if not addressed. The key is to provide rest and the removal of the OT stimuli in the workout program. Because OT has many different faces related to its etiology, the coach must carefully view the athlete on holistic terms. In addition, we often focus so much on the weight room that we forget to realize that the sport coach can do more damage to quality workouts and create OT in arising from their practice demands and supplemental training. Thus, in the case of true OT the key is to start a rest and restoration phase in your training cycle while you further analyze the situation and plan the progression back to a baseline of expected improvement or maintenance. Sport practice and demands play a big role in the total stress on an athlete. Although beyond the scope of this roundtable, psychological factors, coping skills, school learning skills, and nutrition also affect the total OT phenomenon.

O'Bryant:
Within an appropriately planned training cycle, small day-to-day adjustments can be made to carefully manage fatigue

and recovery, maximizing the beneficial effects (see response to previous question 3) while reducing the potential for OT.

A more prolonged intervention is usually necessary when "true" OT has occurred (see response to question 1). A drastic reduction in training volume or intensity, if not total rest for several training sessions (up to several weeks if not months), can be required. This should be followed with a gradual increase in training volume or intensity over several training sessions before normal training levels can be resumed.

Pendlay: The variation of training stress and the variation of training means present within a periodized program should help avoid OT. A good coach should also be mindful of how the athlete responded to the last training period. For example, if the preparatory period before the last competition was successful, a coach might plan a slightly higher volume for the present preparatory period. Or, if a coach has an athlete coming out of a preparatory period who is showing signs of impending OT, he or she might lower the volume of this competitive period as compared with the last one to allow for regeneration and plan a longer than usual transition period after the competition. In the event of OT, volume and intensity should be lowered, and the means of training should be changed. The goal of training should be the same as a transition period: to preserve general conditioning while allowing rest and recuperation.

Stone: See the answers to question 3. Training variables are altered in a manner consistent with the cycle level (i.e., macro, meso, etc)—the primary portion of a periodized training scheme, which minimizes the OT potential, is at the microcycle level (i.e., day-to-day variation). If true OT does occur, immediate rest for several weeks followed by slowly moving back to normal training is a necessity (all done using careful monitoring for the signs and symptoms of OT).

Question 5: There is a lot of Debate in the Current Literature about Nonlinear and Linear Periodization. Can you Comment About These Suggested Permutations of Periodization and How They May be Utilized in the Preparation of Athletes?

Kraemer: My laboratory group and collaborators over the years have used this concept out of necessity because of its suitability for academic sports training situations and ease in administration in multi-competition sports with long seasons (4, 12, 17, 20). The terminology and support that the idea that we are periodizing the training program are vital, but the so-called nonlinear approach is just a way that appears to be more dramatic in its temporal variation during a microcycle than are the standard classical methods. We have had much success here at the University of Connecticut over the past couple of years in our research and with sport teams using this general approach. Our strength coach, Andrea Hudy, has used the undulating format design of training with our women's basketball program and has had a great deal of success that we hope to quantify in the near future in research and journal articles. I like to think that this type of periodization model evolved in the academic calendars with student athletes and sports that were not a so-called single-competition peaking sport. Nevertheless, the variation in the 7- to 10-day cycle is either planned or can be reactive to the changing terrain of the athlete's health, schedule, practice demands, etc. For example, if the coach has a hard practice, a planned power day may not be optimal, so one can switch in the session to a light day for local muscular endurance. This gives a great deal of flexibility to the program. As scientists, we have carefully tried to quantify this in both specific and general models as being more optimal than other forms of training progressions. We have tried to get beyond the level of opinion and provide some data to work with. This is key to my approach in training-program development. Such data seem to support the use of very dramatically different training days, ranging from a base of 3 different training days, for example, to many more with completely different target goals for that training session and very little cross-over of another style of training during that session to allow motor units to be very selectively recruited. Thus, when we are training on a heavy day, for example, with a 3 to 5RM zone for our exercises, there are not a lot of light repetitions performed except for needed warm-up. On light days, one never gets into the resting heavy and power recruitment patterns, thus providing a very different physiological experience for the workout that day.

Here is an example of a nonlinear periodized training program that has been developed to maintain variation in the training stimulus. The nonlinear program allows for variation in the intensity and volume within each week over the course of the training program mesocycle (e.g., 16 weeks). The change in the intensity and volume of training will vary within the 7- to 14-day rotation periods. An example of a nonlinear periodized training program over a 16-week mesocycle would be:

Monday
4 sets of 12 to 15RM

Wednesday
4 sets of 8 to 10RM

Friday
3 to 4 sets of 4 to 6RM

Monday
4 to 5 sets of 1 to 3RM

This protocol uses a 4-day rotation with 1 day of rest between workouts.

The variation in training is much greater within the week. One can easily see that intensity spans over a maximum of a 14RM range (possible 1RM sets versus 15RM sets in the week cycle). This span in training variation appears to be as effective as linear programs. One can also add a "power" training day where loads may be from 30 to 45% of 1RM and release of the mass is allowed if no deceleration exists with the movement of the joint or joints. In fact, we have a whole continuum of choice for the nonlinear workout possibilities that can be cycled though over a 14-day microcycle, depending upon the goals of the athlete (Table 2).

Table 2
Example Training Day Continuum for Strength and Power Loadings for a Nonlinear Periodized Training Program. Any 3-Repetition Range Can Be Used and is Specific to the Type of Exercise and Equipment Being Used in a Training Program

Training zone (RM)	Intensity of training day
1–3	Very, very heavy to very heavy
4–6	Very heavy to heavy
7–9	Heavy to moderate
10–12	Moderate to light
13–15	Light to very light
>15	Very light to very, very light

Power Day Training Day: Plyo's, medicine ball exercises, high velocity, and light percentage using 3–6 repetition limits for attaining peak velocities and maximum accelerations in the workout. RM indicates repetition maximum.

Different from the linear programs is the practice that one trains the different components of muscle size and strength within the same week. Different from the linear methods, nonlinear programs attempt to train different adaptational aspects of the neuromuscular system within the same microcycle. Thus, one is working at different physiological adaptations together within the same 7- to 14-day period of the 16-week mesocycle. A rest or restoration cycle then follows this training cycle. This appears possible and may be more conducive to many individuals' schedules, especially when competitions, travel or other schedule conflicts, practice demands, sickness, etc, can make the traditional linear method structures difficult to adhere to and train large groups of athletes.

In this program, one just rotates through the different protocols. The workout rotates between very heavy, heavy, moderate, and light training sessions. If one misses the Monday workout, the rotation order is pushed forward, meaning one performs the rotated workout scheduled. For example, if the light 12 to 15 workout was scheduled for Monday and you miss it, you perform it on Wednesday and continue with the rotation sequence. In this way, no workout stimulus is missed in the training program. One can also say that a mesocycle will be completed when a certain number of workouts are completed (e.g., 48) and do not use training weeks to set the program length.

Again, the primary exercises are typically periodized, but one can also use a 2-cycle program to vary the small-muscle group exercises. For example, in the "triceps push-down" one could rotate between the moderate (8 to 10RM) and the heavy (4 to 6RM) cycle intensities. This would provide the hypertrophy needed for such isolated muscles of a joint but also provide the strength needed to support heavier workouts of the large-muscle groups.

O'Bryant: Some have described linear periodization as variation of the TI over several weeks of training with nonlinear periodization as variation of the TI and volume over a week with differences from day to day (1). However, by definition, any periodization should be considered nonlinear. Although the general loading process (with respect to initial training levels) overtime may be considered linear, variations in volume and intensity that occur within a microcycle—also represented by microcycles in a mesocycle and mesocycles in a macrocycle—exhibit a nonlinear pattern. Therefore, all periodization is characterized by periods of high intensity or volume alternating with periods of lower intensity or volume to facilitate recovery and to maximize performance (6).

Pendlay: Periodization is, by nature, nonlinear. A particular periodized training program appears linear only if it is viewed in too small a timeframe. Periodized programs can have vastly different frequencies of undulation: One may appear nonlinear when viewed for only a month, whereas another may appear linear unless viewed for more than a year. For example, Chandler (2) noted that the program presented by Stone (6) had been described as linear but would appear nonlinear if one were to view repetitive applications of the program. Poloquin (4) asserts that linear overloading is hardly advisable for the athlete and offers an undulating approach, yet his program could be termed linear if viewed for only 4 weeks. Although there are data that show periodized programs, which both undulate (3) and do not undulate (7) within the experimental time frame, are superior to nonperiodized programs, the optimal frequency of undulation for a periodized program is likely to be specific to the athlete.

Plisk: The term linear periodization has been used to describe training cycles involving gradual, progressive increases in intensity and was originally adopted by Baker et al. (1) from a discussion of problems with linear intensification strategies by Poliquin (2). This term is simplistic and misleading. It would be more appropriate to refer to traditional or nontraditional periodization models because, by definition, periodization involves nonlinear variations in training parameters. This issue is addressed in more detail in letters to the editor by Stone and O'Bryant (3) and Stone and Wathen (4).

Responses to question 2 offer some ideas on permutations and their application. I would add a few general guidelines:

- As mentioned above, all athletes should begin at a basic level and then progress through an intermediate developmental process, whereas few achieve what would be considered the "sport mastery" stage by international standards. It is a serious mistake to perceive the first 2 approaches as being inferior or insignificant and to attempt advanced tactics too early in an athlete's long-term preparation.
- Stressors should be applied strategically, regarding integration rather than isolation of responses to stimuli.
- A periodized plan should reflect an increasing level of micromanagement as the athlete's development progresses. This does not mean that all decisions should be deferred to the coach; instead, more sophisticated variation should be applied on multiple fronts (i.e., training methods and means, within and between cycles).

Stone: By definition, linear periodization is not possible. Therefore, linear periodization cannot be used in any population because it is not possible to achieve (16). Part of the confusion as to terminology stems from 2 common errors:

The first is equating volume of training with repetitions. Although repetitions do influence volume, repetitions are not a reasonable measure of training volume. The volume of strength training is more accurately estimated using volume load (repetitions multiplied by mass lifted). The volume load can be associated with energy expenditure and performance outcomes; repetitions usually cannot be associated with these variables. Although, simplistically, using repetitions to describe a periodization model as linear appears to fit (i.e., 10 to 5 to 3 repetitions), closer inspection of the volume load and TI (average load) and EI (power output) typically shows considerable variation (7).

The second error, and perhaps more serious, is that the term *linear* is often misconstrued to encompass long-term periodization rather then the mesocycle-length model for which the term was originally (and erroneously) applied. Even considering repetitions alone, if one repeated the model for another mesocycle, undulation would be apparent over a long term.

There is little doubt that variation is a key training principle and is a basic tent of periodization; if one considers undulation to be a function of variation in volume, intensity factors, and exercise selection, then:

- All periodized models undulate; otherwise, the definition of periodization must be altered.
- The degree of undulation depends upon how these training variables are manipulated over time.
- The degree of undulation depends upon how many time levels are being manipulated (i.e., macro, meso, micro, daily, summated microcycles).
- The degree of undulation depends upon the type of sport (i.e., seasonal, climatic, etc).
- The degree of undulation depends upon the level of athlete with the degree of undulation increasing with the advancement of the athlete. ♦

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