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Review

The training process: Planning for strength–power training in track and field. Part 1: Theoretical aspects

Brad H. DeWeese [a], Guy Hornsby [b], Meg Stone [a], Michael H. Stone [a,*]

[a] Exercise and Sport Science, Center of Excellence for Sport Science and Coach Education, East Tennessee State University, Johnson City, TN 37614, USA
[b] Kinesiology and Health Sciences, Virginia Commonwealth University, Richmond, VA 23284, USA

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Abstract

The process of strength–power training and the subsequent adaptation is a multi-factorial process. These factors range from the genetics and morphological characteristics of the athlete to how a coach selects, orders, and doses exercises and loading patterns. Consequently, adaptation from these training factors may largely relate to the mode of delivery, in other words, programming tactics. There is strong evidence that the manner and phases in which training is presented to the athlete can make a profound difference in performance outcome. This discussion deals primarily with block periodization concepts and associated methods of programming for strength–power training within track and field.

Keywords: Periodization; Strength–power training; Track and field; Training process

1. Introduction

There is little doubt that the method employed makes a significant difference in the physiological and performance adaptations resulting from a resistance-training program.[1] For example, high-volume programs generally have a greater influence on body composition, enhancement of muscle cross-sectional area, and work capacity factors than do low-volume higher intensity programs. In contrast, high-intensity programs have a greater influence on maximum strength, peak power, and velocity compared to low-intensity programs.[2,3] Evidence also indicates that the level of the athlete results in somewhat different adaptations to training at least quantitatively. For example, among relatively untrained or weak athletes, strength training will provide as great or greater increases in power as compared to power training alone. Furthermore, evidence indicates that prior strength training or having higher maximum strength levels can potentiate further power training.[3–7]

Training should be recognized as a process which prepares an athlete, technically, tactically, psychologically, physiologically, and physically for the highest possible levels of performance.[8] First is the realization that training is a process that requires considerable forethought and planning. Training is multi-factorial in nature; as such the attempt is to exploit known principles of physics, physiology, and psychology in order to maximize the effects of the training stimulus. The training process is vitally concerned with the positive enhancement of performance—therefore the process must provide:

- an appropriate stimulus for adaptation;
- an appropriate means for assessing progress (monitoring);
- and additional means beyond sets and reps (i.e., stimulus) including rest–recovery phases, psychological re-enforcement, daily nutrition, supplements, sleep, *etc*. so that recovery–adaptation is optimized.

The sport training process attempts to take the athletes as close as possible to their genetic limits, thus training is not simply recreational exercise. Considering this concept, a good coach should be viewed in the same context as a good physician. Therefore the training process can be viewed as a prescription.

When developing a training process there are several "realizations" that are major factors in the development of a successful training process:

Every athlete does not progress to the elite level.[9] There is no substitute for innate talent (genetics). There are two aspects to this realization. First, there are genetically linked physiological characteristics that relate to superior performance. These heritable characteristics range from higher testosterone

* Corresponding author.
E-mail address: Stonem@etsu.edu (M.H. Stone)
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concentrations in both men and women to differences in muscle fiber types.[10–12] As a result of these genetic links athletes with specific traits simply are able to perform better in specific sports. For example: athletes with more Type I motor units typically have a higher VO_{2max}, handle lactate more efficiently and have endurance event advantages.[13] Second is the relationship between heredity and the training "window of adaptation".[10,14,15] Everyone responds to a well-planned training stimulus; however, because of heredity some athletes respond to the same program with greater adaptation, and so are able to progress further than typical athletes. Athletes that have both traits are most likely to progress to the elite level.

Being stronger can make a substantial difference in performance. Maximum strength is related to:[4–6,8,16–20]

- Magnitude of force production with greater peak and average forces that may allow for higher velocities and power outputs to be achieved when using submaximal loads;
- Rate of force development (RFD) which can describe faster muscle activation with resultant greater force during critical time periods;
- Superior ability to develop and respond to stretch shortening cycles (SSC);
- Greater peak and average power, which means that work is accomplished at a higher rate;
- Greater absolute endurance, especially high intensity exercise endurance (HIEE) that may reduce "central" (nervous system) fatigue; i.e., more total work can be accomplished;
- Greater postural strength, which describes the ability to hold static and dynamic positions better during performance;
- Some evidence that force sensitivity and sensation is superior (may be a result of strength training partially independent of maximum strength)—ability to appropriately modulate force production is superior;
- Importantly, among weaker athletes (most scholastic and collegiate athletes), strength training alone may produce equal or superior results in terms of RFD, power, *etc*. compared to power or speed training,[4–6,8] particularly when performed in an integrated fashion with sport training programs.

2. Components of the training process

A major component of planning concerns the understanding of both the developmental and conceptual aspects of the training process. Considering that training is multi-faceted, the degree of success achieved will relate to how well a coach learns to plan conceptually and subsequently creates detailed subcomponents oriented to produce superior results. These factors of the training process include the following.

2.1. Construction of the annual plan[8]

The most important aspect of the planning process is the creation of a sound annual plan. The annual plan is a road map for the overall training process and its development is the first step in constructing the athlete's program (the program can be found online at doi:10.1016/j.jshs.2015.07.003 as Table S1). The annual plan lists the coming competitions, the projected testing/monitoring dates and a general guide to conceptual training (periodization and programming).

Conceptually, periodization is a blueprint dealing with fitness phases and timelines. This blueprint allows the coach to project an approximate timeline for when various types of fitness phases (e.g., endurance, strength–endurance, strength, power, speed, taper, *etc*.) will be emphasized, the order of the phases and how long each of these phases will last. The annual plan also contains the programming for the periodized training plan.

Programming deals with creation of appropriate sets, repetitions and exercise selection that make the different phases efficient and efficacious. Programming is a primary factor in fatigue management and directing training toward the desired goal(s). Excessive accumulative fatigue inhibits physiological adaptation to training stimuli, produces non-beneficial psychological aspects and increases the injury potential. Thus a primary aspect of programming deals with appropriate variation of training volume, intensity, and exercise selection such that fatigue is controlled and adaptation is optimized.

The separation of these two aspects (periodization and programming) within the training process is often difficult. Depending upon the type of periodization process chosen (e.g., classic *vs.* block), the programming can be different. Regardless, development of the annual plan is the primary step in creating an efficient and successful training process.

Most important, the success of a training plan resides in how collaborative and willing the head coach and assistant coaches (and strength–conditioning coaches) are to learn the intricacies of, and become fully immersed into, the planning process, a factor that does not always occur. Predictably, for coaches not accustomed to a conceptual planning process, a difficult, but temporary, adjustment period often takes place.

2.2. Factors during the annual plan development

A sound understanding of the basic training principles and their application during training can make a substantial difference in training process outcomes.[1,7,8,21–24] There are four basic training principles: overload, variation, specificity, and reversibility. When these principles are appropriately addressed and properly integrated into the training process as a result of logically applied programming, adaptation is optimized, fatigue management is enhanced, overtraining potential is reduced, and the potential for superior performance is augmented.

2.2.1. Overload

Overload entails providing an appropriate stimulus for attaining a desired level of physical, physiological, psychological, and performance adaptations. Overload can be conceptualized as a training stimulus that forces the athlete beyond normal levels of physical performance. Thus the application of an appropriate overload stimulus can include range of motion, absolute and relative intensity (RI) levels, frequency, and time factors. All overload stimuli will have some level of intensity, RI (percentage of one repetition maximum, 1 RM), and volume. The determination of appropriate overload stimuli for different modes (weights, variable resistance devices, semi-isokinetic devices, *etc*.) of resistance training can be challenging. Quantification of

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some forms of overload or some forms of resistance, for example elastic bands, is at best difficult, particularly as the bands age. For this discussion, the quantification of overload stimuli will deal with weight training.

2.2.2. Variation

Variation describes the removal of linearity from the training plan by manipulating the overload characteristics and degree of specificity. This factor is important for the production of strength–power characteristics and producing a power spectrum. In addition, varying the load may be the most important factor in guiding training toward a specific goal while accounting for "fatigue management". Appropriate variation is an essential consideration for continued adaptation over a long-term training program.[8,25] Variation involves manipulation of the training intensity, speed of movement, volume, rest and recovery periods, and exercise selection. The enhancement of a number of abilities and skills may occur through the emphasis and timeliness of the aforementioned variables in appropriate sequences.[7]

Indeed appropriate sequencing and emphasis of fitness characteristics are part of the foundation of "block periodization". Consideration of several different levels of variation is necessary in a training program (i.e., quadrennial, annual, intermediate, weekly, day-to-day, *etc*.). The level of variation in the training program is directly related to the level of the athlete, with advanced athletes requiring a greater degree of variation as compared to novices and beginners.

2.2.3. Specificity

Specificity is the degree of metabolic and mechanical similarity between the desired performance characteristics and training exercises. The aim of increased specificity throughout the training process is to enhance the transfer of training effect, which is a measure of how much the training transfers to actual sport performance. If athletic performance enhancement is a primary goal, then specificity of exercise and training arguably becomes the most important consideration for selecting methods and modes for resistance training. There are two basic aspects to specificity: mechanical and metabolic.

Mechanical specificity refers to the kinetic (force) and kinematic (displacement, velocity, power, RFD) associations between a training exercise and a physical performance. Mechanical specificity includes movement patterns (e.g., range of movement, open *vs.* closed kinetic chain exercise, *etc*.), peak force, rate of force development, acceleration patterns, and velocity parameters. Conceptually, mechanical specificity has strong support based on observations of inter- and intra-muscular task specificities.[1,8,26,27]

Task specificity is concerned, at least in large part, with the manner in which the motor cortex organizes motor unit activation (intra-muscular tasks) and whole muscle activation patterns (inter-muscular tasks). There is good evidence that both intra- and inter-muscular task specificity aspects play a major role in strength–power training. Basically, the greater similarity training exercise has to the actual physical performance, the greater the probability of transfer.[1,24,28,29] For example, intra-muscular task specificity suggests that for a specific activity only a defined motor unit task group will be activated.[29,30] Evidence of this can be found from practical and research aspects. For example, bodybuilders have noted that to fully develop a muscle, a variety of different exercises for that muscle must be performed; an observation that is supported by considerable research. Several studies[26,27,31–33] have indicated that as a result of resistance training muscle hypertrophy does not occur uniformly throughout a muscle nor does it occur uniformly in different regions (e.g., upper *vs.* lower body). This brings up the possibility of indiscriminant hypertrophy, which could interfere with performance. For example, Abe et al.[26] noted that among sprinters most of the hypertrophy as a result of training was relatively localized in the proximal (upper) portion of the thigh, which tends to reduce the moment of inertia for the hip joint, providing an advantage for sprinting. Thus, training which emphasizes hypertrophy of the distal portion (lower) of the quadriceps may not be as advantageous.

2.2.4. Reversibility

Reversibility describes the loss of fitness that originally accumulated as a result of the training stimulus. This reversal of fitness can occur as a result of two factors.

First, a removal or reduction of the stimuli can result in de-training, which can be considered a "negative" physiological adaptation. For example, muscle atrophy may ensue as the result of resistance training being removed or through a haphazard and marked reduction in volume.

Second, involution of performance characteristics, which can be described as a diminished performance capability, occurs even though the stimulus is still being applied. This type of reversibility often arises in relation to a monotonous, relatively unchanging, program that is likely a result of too little mechanical variation in the training program.

A type of involution can also occur as a result of maladaptations resulting from poor fatigue management (i.e., non-functional overreaching). Detraining is most common after any substantial decrease in volume. Through observation and discussion with athletes and coaches world-wide, involution is not uncommon after 12–16 weeks of training the same basic fitness characteristic (i.e., basic strength, power) even though there can be considerable variation in the exercise type and, to an extent, sets and repetitions.

2.3. Additional training considerations

While the planning process is guided by the four basic training principles, additional factors such as intensity, training volume, training sessions, and training density assist in how well the planning process addresses the tenants of periodization.

2.3.1. Intensity

Intensity is often misunderstood as a component of within-exercise prescription. There are several aspects to the intensity component. Intensity factors are associated with the velocity of movement, rate of performing work, and the rate at which energy is expended.[2] Intensity factors can be separated into two aspects: training intensity (TI) and exercise intensity.[8,34]

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TI is concerned with the rate at which a training exercise or training session proceeds; it can be estimated by the average load lifted per exercise, per day, per week, *etc*., and relates to the training density. For example, within a session, the average load lifted is directly related to the time taken to complete the exercise; thus, for a specified number of repetitions, a heavier load requires more time to complete. Furthermore, a greater number of repetitions lead to a longer duration of the set. Considering these factors, when normal self-selected rest periods (≈2–5 min between sets) are utilized, the work-rate can be dictated by loading and repetition number (Table 1).

The RI is a percent of the 1 RM. The 1 RM value is relatively stable only for advanced strength–power athletes. Thus, using RI to plan resistance-training programs must be carried out with this aspect in mind. Exercise intensity is the actual power output of a movement.

2.3.2. *Training volume*

Training volume is a measure of the total work performed during training and is strongly related to total energy expenditure and subsequent metabolic alterations.[35–39] The resistance training volume is a function of the load, number of repetitions and sets per exercise, the number and types of exercises performed (e.g., large *vs.* small muscle mass), rest periods and the frequency (i.e., number of times per day, week, month, *etc.*) with which these exercises are repeated.

Volume load (VL) is a more reasonable estimate of the amount of work accomplished during training and is commonly used in both research and practical settings. VL is calculated by summing the product of the load and the number of repetitions for each set. This should be done for each exercise within the desired time frame (e.g., weekly, monthly, *etc.*) and the sum total for the combined exercises represents a reasonable estimate of the total work accomplished. However, this approach may not work well if major changes in the exercises performed occur, or if the displacements of the exercises are altered substantially. For example, partial movements replacing full movements (i.e., 1/4 squats *vs.* full squats) during the competition phase. In order to then make better comparisons, the VL for each exercise should be multiplied times the vertical distance the bar moves.[40] The vertical displacement can easily be measured (estimated) with a steel tape measure.

2.3.3. *Training session*

The application of TI and volume can be considered in terms of the training session (i.e., all of the exercises performed during a specific period) or in terms of single exercises. An understanding of overload factors can aid in the programming of training, including methods (i.e., sets and repetitions), velocity of exercise, and exercise selection. The interaction/association of VL and TI can be illustrated by calculating these factors for two sample-training sessions (using the squat as an example). Table 1 displays data for training Day 1, the general preparation (GP) phase, and Day 2 (the late preparation phase). In this example, the VL for Day 1 was larger than that for Day 2 (7000 kg *vs.* 4700 kg); however, the TI was larger for Day 2 than for Day 1 (134 *vs.* 116). VL and TI are inversely related. Furthermore, TI is directly related to the rate at which the load is lifted (kg/s) and is an indication of the rate of training. Calculation of the TI, while reflecting work rate (kg/s), is less time-consuming than measuring and calculating kilograms per second and thus has a practical advantage. The average VL and TI can be easily calculated per week, month, or phase of training. In this manner, using these variables, a reasonable record of training progress can be made.

Table 1
Session 1: general preparation (accumulation) and late preparation/pre-season (accumulation).

	Set	Repetitions	Load (kg)	VL	TI	Duration of set (s)	Work rate (kg/s)
General preparation (accumulation)							
	1	10	60	600		30	20
	2	10	100	1000		35	28.6
	3	10	120	1200		40	30
	4	10	140	1400		45	31.1
	5	10	140	1400		47	28.8
	6	10	140	1400		48	29.2
Total	6	60	700	7000		245	167.7
Mean/set		10	116.7	1167	116.7	40.8	28.0
Late preparation/pre-season (accumulation)							
	1	5	60	300		15	20
	2	5	100	500		17.5	28.6
	3	5	140	700		20	35
	4	5	180	900		25	36
	5	5	180	900		26	34.6
	6	5	180	900		27	33.3
	7	5	100	500		15	33.3
Total	7	35	940	4700		145.5	220.8
Mean/set		5	134.3	671.4		20.8	31.5
Mean/set not including down set		5	134.2	700	134.3	21.8	32.1

Abbreviations: VL = volume load, sum of load lifted (repetitions × mass); TI = VL/repetitions (or mean load/sets).
Based on Refs. 8 and 24.

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2.3.4. Training density (TD)

TD is related to the volume of training and deals with the frequency of training per session, per day, per week, *etc*. TD can also be manipulated to allow higher training intensities to be maintained. For example, training Day 1 might contain three training sessions, each of equal volume while training Day 2 might contain one training session of similar volume to Day 1. Day 1 would have a higher TD and the average intensities of each smaller volume session could be maintained at higher intensities compared to Day 2. One week could consist of six training sessions, while another could contain 12; the TD in Week 2 would be higher. TD can be manipulated to alter planned, functional overreaching and tapering paradigms.[41] For example, TD could be higher in the potentiating aspects of planned over-reaching (high volume phase).

3. Understanding the basic periodization concepts(s)

Periodization provides the overall concept of training and deals with subdividing the training process into specific time periods and fitness phases.[8,42] DeWeese et al.[43] have recently reviewed and discussed various definitions of periodization. One important factor present in the various definitions presented by DeWeese et al.[43] is that fitness phases, inherent in the periodization concept, occur in a cyclical in manner. Indeed the periodization concept and subsequent programming (alterations in exercise selection, volume, and intensity) are designed to remove linearity. It should be noted here that the recently coined term "linear periodization" is a misnomer both by definition and by concept. Periodization is not linear but rather exploits the basic training principles, particularly variation. Furthermore, general periodization terminology is not typically agreed upon and varies from country to country and from author to author.[8] As a result, the following will be used for this discussion. Periodization is the logical, sequential, phasic method of manipulating training variables in order to increase the potential for achieving specific performance goals while minimizing the potential for overtraining and injury through the incorporation of planned recovery.[8,25,43] While terms and the phrasing of time periods differ slightly as a result of programming theories,[8,44] Table 2 describes the various periods of time that are commonly used within the periodization process.

In addition to the time periods described above, periodization calls for the segmentation of the training plan into dedicated fitness phases. In other words, periodization considers that phases of fitness development will move from general to more specific training as the athlete nears competition. These fitness phases are described in Table 3.

3.1. Programming considerations

As a result of incompatibility with the modern training schedule, classic or traditional periodization (TP) may not produce desired effects.[8,45] Current evidence indicates that phase potentiation strategies that are inherent in Block periodization produce superior results, particularly as it relates to athletes (Table 4). Indeed there are several problems inherent in the traditional approach to periodization that may in part or whole be obviated by the block method.

Table 2
Timelines for the planning process.

Term	Timeframe
Annual plan	Approximately a year of planned training
Macrocycle	Several months to approximately 1 year. Consists of five phases related to fitness emphases: (1) general preparation, (2) special transition (1st transition), (3) competition, (4) taper, (5) active rest (2nd transition). This period of time typically contains summated mesocycles
Mesocycle	The addition of summated blocks where several weeks (typically 4—16 weeks) align to allow for the accumulation, transmutation, and realization from a training stimulus
Summated microcycles	The linkage of single weeks in which the volume and intensity of training are manipulated in a manner leading toward achieving a specific goal. (e.g., 3 weeks of increasing volume followed by an unload week). A summated microcycle can also be termed a "block" which associates with a concentrated load in which one aspect of fitness is being emphasized while all others aspects are de-emphasized
Microcycle	A period of several days, also known as summated sessions, that share a similar theme or goal
Session	A single training practice or workout

1. The modern competition schedule is not in concert with TP timelines. Potentially an athlete cannot hold a true peak for more than 3 weeks,[46–49] which might work well if there is only one major competition for each macrocycle; however, there may be multiple important competitions, sometimes relatively close together. Thus, the TP approach that contains only a limited number of peaks likely will not result in adequate outcomes.
2. Many coaches (not understanding all of the subtleties of periodization) attempt to increase the volume of many different training variables simultaneously. This approach can cause difficulty in fatigue management due to high volumes of training as well as create physiological adaptations, which do not favor the goal of the periodization phase. It is very difficult and potentially less productive to attempt the simultaneous development of different physical and physiological characteristics or motor abilities.[8,25,49,50] This loss of productivity can occur for several reasons such as: (A) simultaneous training of fitness characteristics typically result in a substantial increase in training volume that can increase recovery time;[28,36,51,52] (B) high volume or mixed training methods combining endurance and strength–power related training can reduce effectiveness of training direction (i.e., achieving specific goals) and stagnate gains in performance and usually favor endurance over strength and power.[52–59] Thus, the goals of the training program could be compromised. One aspect that can compound the problem associated with mixed training methods (i.e., simultaneously targeting multiple skill and fitness variables) is consistent training to failure or near failure (i.e., high absolute or relative intensities)—a problem that is particularly prevalent for resistance training.

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Table 3
Fitness phases.

Term	Timeframe
General preparation	Typically denotes a higher volume, low intensity, relatively low mechanical specificity phase with the intention of raising sport specific fitness, which includes altering body composition and raising work capacity
Special preparation	A relatively high volume, low to moderate intensity, higher mechanical specificity oriented phase. A portion of this phase typically emphasizes the athletes' ability to repeat exercise with a greater mechanical specificity. This phase can be used to transition from higher volume, less-specific GP training to a higher-intensity, very specific training phase that closely associates with competition
Competition phase	Commonly refers to a moderate to low volume phase with moderate to high intensity that is mechanically specific. The purpose is to maintain fitness while enhancing technical consistency/efficiency. The competition phase can last several months and may contain periods of mini-preparation, if volume reduction should last more than 12–16 weeks. These mini-preparation periods may include periods of functional overreaching which appear to enhance competition performance if timed correctly
Peaking phase	A segment of the competition phase lasting a short time (usually ≤4 weeks), that takes place just before major competitions. During the early portion of peaking, volume can be reduced and TI (or exercise intensity, depending on the sport or performance goals) is increased or maintained at relatively high levels. Typically, during the last few days before important competitions, intensity factors are also reduced to encourage adequate recovery. The later portion of a peaking phase (typically 8–14 days), when volume is markedly reduced, is referred to as a "taper".[8,46,47] A taper consists of a reduction of training volume in order to reduce fatigue and take advantage of the fitness–fatigue paradigm.[8,25,46,47] A taper can be coupled with planned overreaching in order to boost performance beyond that of a typical taper
Active rest	A period of recovery after peaking and major competitions (usually 1–2 weeks) using a reduce volume and intensity of training). Recovery includes healing and rehabilitation of any injuries that may have occurred as well as recovery from the emotional rigors of competition. Complete rest allows sports-specific fitness to deteriorate to a degree from which it is difficult to recover without extensive training. Compared to complete rest, AR allows for less deterioration of fitness and a faster return to peak fitness during the next cycle. AR usually lasts about 1 week. At times the training may be re-directed into another activity to improve the psychological/emotional recovery aspects (make the training more recreational)

Abbreviations: GP = general preparation; TI = training intensity; AR = active rest.

Some of these problems associated with TP were recognized by Matveyev[42] and Matveyev and Zdornyj[59] as early as the late 1960s. However, training paradigms that addressed these problems were not well formulated until the 1970s and 1980s. The basic concept of Block periodization was formalized during this time period by Verkoshansky,[60,61] Issurin and Sahrobajko,[55] and Issurin[62] in Europe (Soviet Union) and by Stone and colleagues[44,63] in the US, particularly for strength–power training.

3.2. Block programming

Block periodization depends upon several observations and characteristics.[8,44,50,62,63] This begins with the observation that the development of specific physiological/performance characteristics at high levels cannot be sustained for long periods of time. In conjunction, the attempt to simultaneously develop multiple characteristics is often counterproductive. As a result, emphasizing training variables at different points of the training year can develop specific performance characteristics. This tenant is met through the utilization of a series of "concentrated loads" that are sequenced together at the appropriate time in order to produce superior results. In addition, "planned functional overreaching" can promote additional adaptation while taking advantage of the fitness–fatigue paradigm. Collectively, the summating effects of concentrated loads coupled alongside planned functional overreaching strategies may positively affect future training through phase potentiation, as a result of the accumulation of residual effects.

A comparison of block and TP is shown in Table 4. These differences highlight the conceptual advantages of block periodization methods. Coaches should understand that the differences between winning and losing, a medal and no medal, are often extremely small. In the last eight Olympics the differences between 1st (Gold) and 4th (no medal) has been less than 1.5% for most sports and events. Thus training advantages, even those seemingly trivial, may in actuality be quite large in the realm of competitive sport. There is little doubt that Block periodization concepts and methods can offer training advantages.

4. Factors affecting the training process outcome

There are a number of factors that will positively or negatively affect training outcomes; these include diet, supplements, sleep, *etc*. This discussion will center on those directly related to training.

First is the realization that rapid gains are not always in the overall best interest of the athlete. Fig. 1 shows the relationship between the intensity of training and performance gains. Generally, the higher the relative intensity, the faster the gains occur; however, this takes place by sacrificing the final performance level and the length of time a high level of performance can be sustained. Thus, in settings in which athletes may take time off (e.g., summer, Christmas break, *etc*.) very intense (or very high volume) programs designed to get the athlete back into shape rapidly may ultimately decrease the level of attainable performance. Training programs are likely to produce rapid gains in performance, early performance plateaus, and rapid diminished returns including:[8,41,64–68]

- Constant high absolute or relative intensity (e.g., Bulgarian System in weight-training)
- Weight-training use of RM zones and subsequent training to failure on a regular basis;
- Linear programs using consistent increases in intensity.

Next is the ability of the athlete to make maximum efforts when necessary. Fig. 2 illustrates the relationship between

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Table 4
Block periodization studies among athletes (preserved ecological validity).

Study	Athletes	Length	Comparison	Major finding	Comments
Issurin and Sahrobajko,[55] Issurin et al.[74]	23 male canoe/kayak athletes	3 years (seasons)	TP *vs.* BP	BP > TP on water power output, propulsion efficiency, ergometer power. Superior performance in international events	BP group superior performance in world level events
Harris et al.[7]	42 American football players HF = 13 HVP = 16 BP (COM) = 13	9 weeks	BP (Com) *vs.* HF and HVP	BP improved to greater extent and on wider variety of measures than other two groups	All groups preceded study using 4 weeks SE CL; Planned comparison: COM (BP—only group finishing block); Winter workouts (sprits, jumps, *etc.*)
Garcia-Pallares et al.[54]	World class male kayak	2 years (seasons)	TP *vs.* BP	BP > TP VO_{2peak} (11% and 8.1%) BP > TP PS (peak), Pw (peak), and SR (peak)	BP showed greater improvements even though TP cycle was 10 weeks and 120 training hours longer than the BP cycle
Breil et al.[53]	21 alpine skiers (junior elite) BP = 13 TP = 8	11 days	TP *vs.* BP	BP > TP VO_{2peak}, cycle PP, and power at Ven Threshold	
Mallo[75]	77 male professional soccer players	4 years (seasons)	BP *vs.* traditional soccer training	BP performed (competition and measures, e.g., 1RM, speed endurance, *etc.*) better than traditional	Each season divided into three complete blocks; Team performance was assessed in competition, by percentage of points by team in each match examined in relation to the training phase
Painter et al.[76]	26 day = 1 track and field strength power BP = 12 DUP = 14	10 weeks of resistance training with normal training	BP *vs.* DUP	Based on ES and % change BP > DUP in 1 RM squat, IPF, and RFD; BP > DUP work efficiency	Groups equated initially on 1 RM, event and sex; DUP performed approximately two times more work
Bakken[77]	World class X-country and biathlon	5 weeks of intensive endurance training	BP *vs.* T training	BP > $VO_{2peak,}$ time to exhaustion	
Rønnestad et al.[58]	15 male cyclists BP = 8 TP = 7	12 weeks of preparation training	TP *vs.* BP	BP > TP: VO_{2max}, 2 mmol/L La, and during 40 min trial and >Hg mass	Similar V and I
Rønnestad et al.[78]	19 male cyclists BP = 10 TP = 9	4 weeks endurance training	TP *vs.* BP	BP > TP: VO_{2max}, 2 mmol/L La, and PP (Wingate) TP did not change	Similar V and I
Bartolomei et al.[79]	24 strength power athletes (track and field, rugby) BP = 12 TP = 12	15 weeks resistance training	TP *vs.* BP	BP > TP Upper body strength measures (impulse optimal PP, 1 RM)	Changes based on ES—also possible to conceptualize as block *vs.* block as TP was actually divided into two summated microcycles;
Rønnestad et al.[80]	19 elite cross-country skiers BP = 10 TRAD (TP) = 9	5 weeks endurance training	BP *vs.* TP	BP > TP Larger peak power output and power output at blood lactate concentration of 4 mmol/L Maximal oxygen uptake increased by 2% ± 2%	Similar V and I

Notes: These 11 studies show and discuss comparisons of block periodization protocols *vs.* other types of training including traditional periodization methods of training. They are quite unique in that the studies all used athletes. These studies include a variety of sports, training characteristics (e.g., strength, endurance, *etc.*) and a variety of timelines from very short (11 days) to 3 years (seasons). In every case the block model (BP) showed evidence of superior adaptation.
Abbreviations: BP = block periodization; TP = traditional periodization; HF = high force group; HVP = high velocity high power group; COM = combination group; SE = strength endurance; CL = concentrated load; DUP = daily undulating periodization; ES = effect size; IPF = isometric peak force; RFD = rate of force development; TRAD = traditional; PS = paddling speed; Pw = power output at VO_{2peak}; SR = stroke rate; PP = peak power; La = lactate; T training = traditional trainning.
Preserved ecological validity—ecological validity deals with studying groups in their natural or typical cultural setting so that generalization to other similar groups has a greater validity. Thus studies with athletes in their normal training environment preserve ecological validity.
Based on Issurin.[62]

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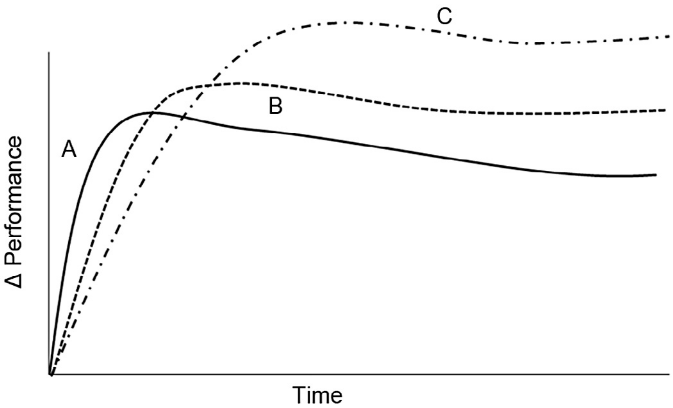

Fig. 1. Characteristics of different prolonged average intensities. (A) Rate of gain is directly related to average intensity of training; (B) final level of performance is inversely related to the average rate of gain; (C) rate of gain is inversely related to the length of time (time period) that peak performance can be sustained. Thus for: 1. initial rate of gain A > B > C; 2. final level of performance C > B > A; 3. time period of maximum performance C > B > A.

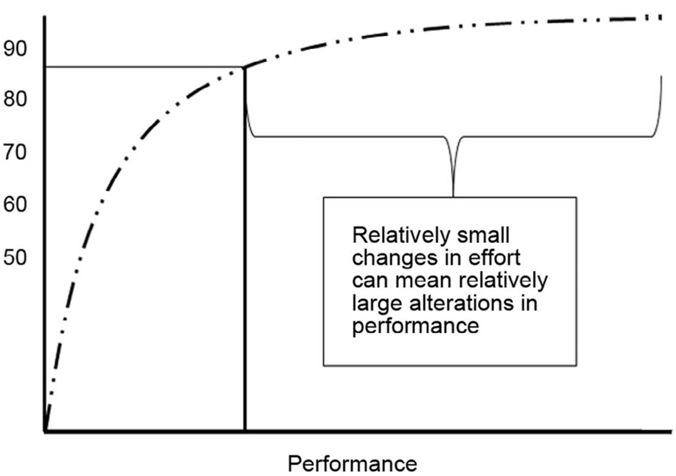

Fig. 2. Relationship between effort and performance. Based on Bannister.[69,70]

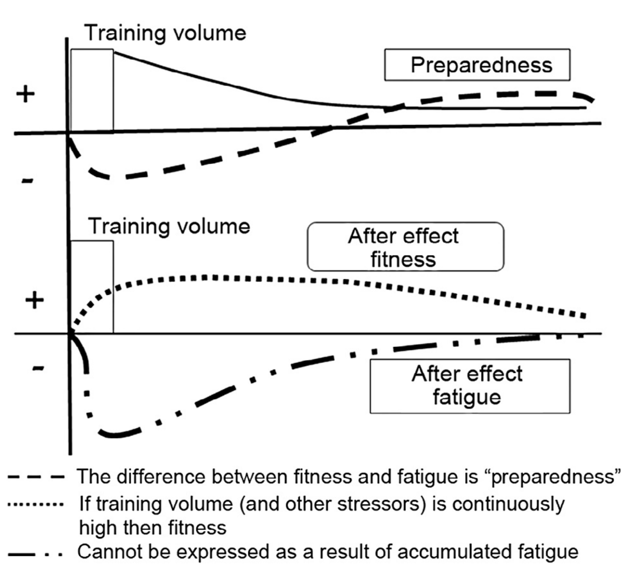

Fig. 3. Fitness–fatigue relationship. Based on Stone et al.[1] and Chiu and Barnes.[68]

effort and performance.[69–72] Essentially, athletes who are encouraged to put forth high efforts and train with intent derive considerably greater performance, a factor that would transfer to both a greater training stimulus and to better competition performance. This is especially important in resistance training as maintaining higher velocities for a given load can enhance strength, velocity, and power gains even among stronger athletes compared to self-selected velocities.[73] Thus, part of the commitment (and realization) on the coach's part is to instill, teach, and promote that the athlete make a maximum effort each repetition.

We must also realize that training has consequences extending far into recovery.[25,68] Residual, or after effects, persist even after the training stimulus is reduce or terminated. The Fitness–fatigue paradigm describes the interplay between the underlying mechanisms (fitness) and accumulated fatigue as a result of training (Fig. 3).

Fitness and fatigue can be conceptualized as primary after-effects of training. Fitness includes the mechanisms underlying fitness characteristics such as strength, power, and endurance. Both the volume and intensity of the training stimulus contribute to the after-effects. Accumulative fatigue is a primary cause for the inability to completely express the fitness characteristic, and thus represents the mechanisms that interfere with fitness expression. There are likely multiple fitness after-effects and multiple fatigue after-effects each associated with different underlying characteristics (e.g., strength, RFD, power, *etc*.). Although each specific fitness and fatigue after-effect is independent of each other, each has an additive effect. Of primary concern is the summation of fatigue after-effects (accumulative fatigue). As training progresses fitness improves and fatigue accumulates, particularly if the volume of training is increased.

The difference between fitness and fatigue is termed "preparedness" and this represents the potential to perform well. It has been shown that as the volume of training is reduced fatigue declines at a faster rate than fitness, and preparedness increases until fitness deteriorates as a result of the prolonged decrease in training volume. Thus preparedness reaches its peak at some point shortly after the training stimulus has been reduced. This is the basis of a taper and to an extent the mechanisms of planned or functional overreaching. It is also to an extent the basis of Block Periodization.[7,53–55,58,75–80]

The follow-up to this article will further detail the benefits of Block periodization through a discussion on how concentrated loads are sequenced and timed. Furthermore, this review will provide evidence on how periodizing the training plan through block programming can augment the strength and power characteristics required for most track and field events.

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