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Review

The training process: Planning for strength–power training in track and field. Part 2: Practical and applied aspects

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Abstract

Planning training programs for strength–power track and field athletes require an understanding of both training principles and training theory. The training principles are overload, variation, and specificity. Each of these principles must be incorporated into an appropriate system of training. Conceptually, periodization embraces training principles and offers advantages in planning, allowing for logical integration and manipulation of training variables such as exercise selection, intensification, and volume factors. The adaptation and progress of the athlete is to a large extent directly related to the ability of the coach/athlete to create and carry an efficient and efficacious training process. This ability includes: an understanding of how exercises affect physiological and performance adaptation (i.e., maximum force, rate of force development, power, *etc*.), how to optimize transfer of training effect ensuring that training exercises have maximum potential for carryover to performance, and how to implement programs with variations at appropriate levels (macro, meso, and micro) such that fatigue management is enhanced and performance progress is optimized.

Keywords: Periodization; Programming; Strength training; Track and field; Training process

1. The training process: putting it together

As described by DeWeese et al.,[1] the training process describes the blending of many factors that provide for athlete enhancement. In addition, these training aspects are embodied within the annual plan. This comprehensive list of aspects can include the training plan (length of periods, exercises, workloads), forms of recovery (nutrition, sleep, physiotherapy), sport-science (evidence-based approach to training), and the athlete-monitoring program (tests that ensure proper development through objective assessment).

Periodization provides the basic framework in terms of fitness phases and timelines, while programming involves making decisions related to the number of repetitions, sets, intensity of exercise and training, volume, and rate of progression. As introduced in Part 1,[1] the "block" method of meeting the tenants of periodization has been demonstrated to be a superior method attacking the complications associated with training and competition for the majority of track and field events in a modern competition setting. For instance, Block Programming may promote more efficient training priorities while maximizing the maintenance of strength–power characteristics, which can ultimately bolster the tapering/peaking phase leading into a major competition.

2. Periodization

Recall that periodization is an integral part of annual planning and represents the theoretical framework for developing a training program. Based on the definition presented in Part 1, a basic tenet of periodization is training nonlinearity. The primary goals of periodization include (a) an appropriate balance of training loads and competitive readiness during the season, (b) fatigue management and the reduction of overtraining potential, and (c) adequately staging and timing of the peak. These goals are primarily met by appropriate variation (non-linearity), which can be achieved through the manipulation of volume, intensity factors, and exercise selection. Coaches should recognize that variation should occur at the larger level (e.g., quadrennial plan) down to the daily training sessions.

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2.1. Traditional periodization

Traditional-periodized training can be divided into three stages or levels: the macrocycle (long-length cycle), the mesocycle (middle-length cycle), and the microcycle (short-length cycle, or day-to-day variation). Each macro- and mesocycle generally begins with high-volume, low-intensity training and ends with high-intensity, low-volume training. The macro- and mesocycle can consist of four fitness phases: (a) preparation (general and special), (b) competition, (c) peaking, and (d) transition or active rest. These phases typically have different goals and can require different degrees of variation within the training elements. It should be noted that a mesocycle can also consist of largely one phase (preparation, *etc*.) depending upon the level of athlete and their needs. Beginners often progress quite well using some variation of traditional programming in which alterations in volume and intensity typically occur more gradually.[2] However, advanced athletes require greater variation in exercise selection, volume and intensity of training compared to beginning athletes to promote continued adaptations to the training stimulus.

2.2. Block periodization

Evidence indicates that most advanced and elite athletes use some form of periodization. Greater variation is necessary as a result of several factors, including: (a) advanced athletes train with greater volumes and intensities than beginners and novices, and may be closer to a non-functional overreaching or overtraining threshold, thus require greater fatigue management resulting from greater variation and (b) as genetic limitations are approached, greater variation and novel approaches to training may be necessary to adequately disturb homeostasis and "provoke" additional adaptation. Thus, several creative resistance-training approaches can further stimulate strength–power adaptations.

Block periodization uses the idea of linking together a sequence of concentrated loads. A concentrated load is unidirectional, meaning that one characteristic of physiological development (e.g., endurance, strength, power) is being emphasized. This does not mean that training is exclusive, but rather that a particular fitness characteristic is being emphasized and other aspects of training de-emphasized through the implementation of retaining loads (minimal doses to maintain specific fitness characteristics). Concentrated loads produce after-effects or residual effects that persist into the next phase. In other words, these after-effects potentiate the next concentrated load.

Sequenced training (which refers to phase potentiation or block periodization) offers advantages not inherent in other forms of training. For example, prior exposure to strength training and resultant increased maximum strength levels can potentiate speed/power gains during a concentrated load of power training. Data from both longitudinal and cross-sectional studies[3–5] indicate that sequenced training, heavy weight training over a few weeks followed by speed–strength training, or combination training (heavy training plus high-power or high-speed training) produces superior results in rate of force development (RFD), speed, and power gains compared to heavy weight training or speed–strength (high power high velocity) training alone. More importantly, evidence indicates that this type phase potentiation (sequenced training) can alter a wide variety of athletic performance variables to a substantially greater extent than either heavy weight training or speed–strength training.[3,6]

2.2.1. Summated microcycles

Evidence suggests that sequenced training can produce superior results in terms of improving speed and power. This model depends upon the idea that after-effects from the preceding phase potentiate gains in the following phase.[7] This phase potentiation (block periodization) model is built upon microcycles and summated microcycles.

A microcycle is the shortest repeatable cycle and is typically specified as 1 week. Microcycles (weeks) can be grouped together to create a summated microcycle (SM). Each SM presents a specific pattern of volume and intensity loading. Therefore, an SM represents a form of concentrated load. The SM can be repeated throughout a mesocycle such that specific stimuli are "re-presented" in a cyclical fashion. Generally, an SM consists of 4 ± 2 weeks, as this period of time appears to be optimal for summating cumulative after-effects (residual effects) while being short enough to ensure that involution does not occur.[8,9] A typical SM would be one in which volume and intensity is increased for 3 weeks followed by an "unload" week, creating a 3/1 SM.[6] The unload week, which creates a marked variation in workload, can be used to reduce overtraining potential and allow for adaptation or "supercompensation".

2.2.2. Furthering phase potentiation through functional overreaching

Conceptually, "supercompensation" is essentially an overshoot in the level of a specific variable past the initial baseline. In advanced athletes, if "supercompensation" of maximum strength, power, and speed are training goals, then additional strategies may be effective. One such strategy entails planned overreaching or functional overreaching. Planned overreaching is an intentional, substantial, sudden increase in volume or intensity that places the athlete in a state of functional overreaching. Functional overreaching occurs provided the overreaching (increased volume/intensity) phase is not too extensive or long lasting. Thus, for resistance training, overreaching can occur as a result of a large increase in volume-load (VL) (or other conditioning activities depending upon the event/sport). Caution should be taken as overreaching can result in chronic fatigue and other symptoms similar to the initial stages of overtraining.[10] Provided that the overreaching phase is not too extensive, a return to normal training volumes can result in a super compensatory effect, promoting an increased performance. Performance improvements can be associated with alterations in the anabolic state which may be coupled with changes in the testosterone:cortisol (T/C) ratio.[11,12] By carefully planning the overreaching phase with a subsequent return to normal training, performance may be substantially enhanced, especially prior to an exponential taper.

2.2.3. Variation within phase potentiation

Variation is necessary for the reduction of non-functional over-reaching, overtraining potential, and for general fatigue management. Reduction of over-reaching/overtraining is better accomplished within the SM and particularly the microcycle than at other levels of variation. At the advanced level, generally, relatively heavy and intense training loads are essential for superior athletic achievement; however, constant or very frequent heavy loading can markedly increase "training strain" which can augment the potential for poor or even negative training outcomes, including increased injury.[13–15] Data from both human[13,16,17] and animal[18,19] athletes indicate that multiple "light" days within a microcycle can allow a given training load to be accomplished with a greater potential for positive adaptations and fewer negative outcomes.[13,19,20]

Some of the negative effects associated with accumulative fatigue include alterations in maximum strength, particularly one's Tr_{max} (training 1 RM). For example, quantitative observations by the authors indicate that as a result of accumulative fatigue, Tr_{max} can decrease across a microcycle where the 1 RM representing Tr_{max} on Monday may be substantially lower by the end of the week (e.g., Friday). Thus, if accumulative fatigue is not considered, loading based on a percentage of Tr_{max} (or a contest maximum) may actually represent a much larger percentage of the true maximum strength level by the end of the microcycle. However, appropriate variation in volume and intensity can offset fatigue-induced alterations in Tr_{max}.

2.2.4. Variation within the microcycle

Although there are several methods of creating alterations in training variables, variation can efficiently be produced by using a heavy/light day system. Appropriate variations in volume and intensity of training are important to allow adequate recovery from intense training sessions and reduce the chance of accumulated fatigue and overtraining. Additionally the heavy and light days ensure that a variety of power outputs will be used, potentially resulting in beneficial alterations to the power–load spectrum.[3,4]

Table 1 illustrates an example in which the emphasis of training is on development of leg and hip strength primarily using the squat. In this example, several factors must be considered. The first aspect is the level of the athlete: this type of variation in intensity will not work as well with beginners because of their Tr_{max} instability. The second aspect is that training intensity is altered as a result of variations in relative intensity (RI). The alterations in RI should occur for two primary reasons: fatigue management and in order to preset the athlete with a broad spectrum power–load curve. It should be noted that the exact percentage used should change in accordance with individual athlete characteristics, the type of exercise, the set/repetitions scheme, and fatigue level. Because of these factors a percentage range (based on 1 RM) can be used. This range can help obviate potential problems, especially as it concerns accumulative fatigue. With reference to the example in Table 1, an athlete might be capable of 187 kg on Monday but only 170 kg on Friday for three sets of five repetitions. Regardless of the load, for heavy or light days, maximum efforts should be made in order to maximize adaptations.[21,22]

Perhaps a better method to help obviate problems associated with alterations in Tr_{max} is the calculation of an RI based on specific set and repetition configurations rather than a 1 RM. In this manner the RI may be conceptualized as more of a function of the work to be accomplished (a summation of sets and reps) rather than repetitions as a function of the 1 RM (Table 2). This method of variation has been used successfully for over 20 years by the authors.

However, in creating successful microcycle variation, the effects of other training activities must also be considered.

2.2.5. Balancing the workload

Within track and field, sprinting, jumping, throwing, and other conditioning exercises are also a part of the overall training program. As a result, the combined energy demands and physical/emotional stress must be taken into account. In this context, planning and tracking alterations by VL can be more valuable than simply tracking changes in intensity (load) alone. VL is altered with the type of exercises, repetitions, and intensity.

It should be noted that even when the load is constant addition or deletion of repetitions alters the VL, and therefore the total work accomplished. Importantly, a substantially higher volume of work (e.g., 3 sets of 10 *vs.* 3 sets of 5) will require substantially more time and energy for recovery.[23–25] However, higher intensities of training can require greater recovery time and energy when VLs are similar because of higher and prolonged energy consumption during recovery.[26]

Alterations in training intensity (TI) can also strongly affect the VL, as noted in Tables 3 and 4. For example: using constant sets and repetitions but increasing the loading (TI) will produce an increase in VL (i.e., total work) and total energy expenditure (exercise plus recovery). In other words, a greater increase in TI will result in a more substantial increase in energy expenditure.

Table 1
Example of squat training program.

	MON	TUE	WED	THU	FRI	SAT	SUN
RI	H	R	MH	M	R	M	R

Notes: Squats: MON and THU: 3×5 at target load (after warm-up); Pulls: WED and SAT; Squat $Tr_{max} = 220$ kg; Heavy (H) = 80%–85%; Moderately heavy (MH) = 75%–80%; Moderate (M) = 70%–75%; R = rest; relative intensity (RI) = % of training maximum (Tr_{max} or 1 RM) for 3×5.

Table 2
Relative intensity based on attainable loads for sets and repetitions.

Relative intensity	Percentage of set-rep best (%)
Very heavy	100
Heavy	90–95
Moderately heavy	85–90
Moderate	80–85
Moderately light	75–80
Light	70–75
Very light	65–70
Rest	—

Table 3
Alterations in volume load (VL) resulting from alterations in repetitions.

Set	Day 1			Day 2		
	Repetition	Load (kg)	VL (kg)	Repetition	Load (kg)	VL (kg)
1	10	60	600	5	60	300
2	10	100	1000	5	100	500
3	10	140	1400	5	140	700
4–6	30	170	5100	15	170	2550
6	60[a]	135[b]	8100[a]	30[a]	135[b]	4150[a]

Notes: Day 1: 3 × 10 repetitions (target load); Day 2: 3 × 5 repetitions (target load).
[a] Total values.
[b] Mean values.

Table 6
Mesocycle for improving maximum strength.

	MON	TUE	WED	THU	FRI	SAT	SUN
WTVL	MH	R	MH	R	ML	L	R
RV	M	L	ML	R	L	L	R
TTV	L	M	R	ML	L	R	R

Refer to Table 2 for intensity variations.
Abbreviations: WTVL = weight-training volume load; RV = running volume; TTV = technical training volume; MH = moderately-heavy; M = moderate; L = light; R = rest; ML = moderately-light.

Thus, various combinations of TI (loading) and repetition alterations can result in substantial changes in VL and work accomplished. Thus, these combinations can be used advantageously to alter volume and intensity in order to combat accumulated fatigue and to alter the load–power spectrum.

In actual practice, increases in load often necessitate additional "warm-up" sets. The designation of heavy and light days based on VL must take into consideration the TI, RI, number of sets, repetitions, and the trained state. Table 5 illustrates data from heavy and light days within a microcycle in which exercises were repeated.

From this example, it can be observed that a reduction in target load by 20% (along with appropriate alterations in warm-up sets) can result in a reduced VL of approximately 21.5%. Because total energy expenditure is related to the VL, care must be taken in "matching" the resistance-training program with the requirements for other aspects of conditioning. For example: if one fitness characteristic is being emphasized, such as adaptations in maximum strength, then a light day for training must remain a light day. One must realize that markedly increasing the amount of work performed in non-strength-training exercises on a light strength-training day actually results in a heavy-workload for that day. This obviates the purpose of having a light day and may actually increase the probability of negative adaptation. So, in an event that requires both strength/power training and conditioning aspects, such as the decathlon, care should be taken so that workloads for individual components complement each other. Table 6 provides an example of a mesocycle in which the goal is improving maximum strength, note that different aspects of training can be adjusted so that the stimulus for strength development is not diminished. If technical training becomes that priority, for example, during certain aspects of decathlon/heptathlon training, then a different schedule would be appropriate (Table 7).

Table 4
Alterations in volume load (VL) resulting from changes in training intensity.

Set	Day 1			Day 2		
	Repetition	Load (kg)	VL (kg)	Repetition	Load (kg)	VL (kg)
1	5	60	300	5	60	300
2	5	100	500	5	120	600
3	5	140	700	5	160	800
4–6	15	160	2400	15	180	2700
6	30[a]	130[b]	3900[a]	30[a]	147[b]	4400 [a]

Notes: Day 1: 3 × 10 repetitions (target load); Day 2: 3 × 5 repetitions (target load).
[a] Total values.
[b] Mean values.

3. Phase potentiation for power development

Power output is arguably the most important characteristic for most athletes to develop.[27] The rationale behind this argument is that because power is a work-rate, the athlete who is able to get work accomplished at the highest rate wins.

Based on a review of the literature and mathematical modeling, Minetti[28] and Zamparo et al.[29] present evidence that a sequential training protocol follows an order of: (1) increasing cross-sectional area (CSA) also referred to as hypertrophy, (2) followed by an increase in central effects and enhancement of force production, and (3) completed by the development of

Table 5
A heavy day and a light day within a microcycle.

Day	Exercise	Set	1	2	3	4	5	6	7	Total
Monday	Squats	(1 RM = 200)	300	500	700	900	900	900	400[a]	4600
Monday	Push press	(1 RM = 100)	250	300	400	400	400	200[a]		1950
Monday	Incline press	(1 RM = 140)	300	500	600	600	600	300[a]		2900
	Total									9450
Thursday	Squats	(1 RM = 200)	300	500	725	725	725	450[a]		3425
Thursday	Push press	(1 RM = 100)	250	300	325	325	325	250[a]		1575
Thursday	Incline press	(1 RM = 140)	300	400	475	475	475	325[a]		2450
	Total									7450

Notes: Monday's volume load: (heavy) (3 × 5 at target × 85%); Thursday's volume load: (light) 3 × 5—target sets reduced by 20% of Monday's load.
[a] Reduced load sets (down sets) for power–load spectrum.
Abbreviation: 1 RM = 1 repetition maximum.

Table 7
Mesocycle for improving technical training.

	MON	TUE	WED	THU	FRI	SAT	SUN
WTVL	MH	R	L	R	L	R	R
RV	L	M	R	M	R	ML	R
TTV	H	L	M	MH	R	M	R

Refer to Table 2 for intensity variations.
Abbreviations: WTVL = weight-training volume load; RV = running volume; TTV = technical training volume; MH = moderately-heavy; M = moderate; L = light; R = rest; ML = moderately-light.

additional nervous system effects through power training that emphasizes greater task specificity which results in greater strength and power gains.

This conceptual model is supported by the observation that although bodybuilders show marked hypertrophy (increased CSA) they are not usually as strong or as powerful as powerlifters or weightlifters.[27,30,31] Thus, additional high force training can be necessary to improve the force generating capabilities of typical bodybuilders. Further support for this progressive sequence within the concept of block periodization[4,5,7] comes from Cormie et al.[32] and Harris et al.[3] who demonstrate that higher initial maximum strength levels can potentiate power gains when switching from an emphasis on maximum strength training to power training.

Within this conceptual framework, the first step in power development deals with developing a larger muscle CSA and a higher work capacity. This is best accomplished through a higher volume of exercise with an intensity of ≥60% of the 1 RM representing a threshold for optimum CSA gains[33] and loads as high as 80% may be optimal for markedly increasing the Type II/Type I CSA ratio.[34] Although, initially, higher repetitions preset may offer hypertrophy advantages, it should be noted that over a long-term (year) the set and repetition scheme may make little difference provided the total volume is sufficient.[31,35]

The second step in this process would be the emphasis of basic strength training. It should be noted that increasing strength is not simply associated with lifting a heavier weight, but should be viewed as a vehicle for alterations of several factors including RFD and power. For example: heavy weight training can produce positive performance effects in the entire force–velocity curve among untrained and relatively weak participants.[3,32,36–38] Evidence indicates that among relatively weak athletes, increasing maximum strength can improve RFD and power as much or more than high velocity or power training.[38,39] Dynamic training offers greater carryover (specificity) compared to isometric. Although isometric training can result in an increased peak rate of force production and velocity of movement, especially in untrained subjects,[40] the isometric training effect on dynamic explosive force production is relatively minor, particularly among well-trained athletes.[36,41] However, an important consideration for this 2nd step is that increasing maximum strength likely potentiates further gains in power.[4,38,39]

The final step, after achieving a reasonable strength level, deals with prioritizing power-oriented training. Both observational and objective evidence indicate that among advanced strength-trained subjects, high-velocity training is necessary to make additional alterations in the high-velocity end of the force–velocity curve.[4,36,38] Although several parameters can be initially affected, over a long-term the primary effect of traditional heavy weight-training is increased maximum strength, especially as measured by a 1 RM. In contrast, the primary effect of typical ballistic training is an increased rate of force production and velocity of movement.[4,36,37,41] Additionally, task specific high-power training can alter a wide range of athletic performance variables to a greater extent than does traditional heavy weight-training, especially in athletes with a reasonable initial level of maximum strength.[4,42]

3.1. *Modes of developing power*

While a high maximum strength level can potentiate the development of high-power outputs and increased movement velocity,[43,44] the type of training program (i.e., high-volume, high-intensity) can make a marked difference in the primary type of adaptation (i.e., body composition, strength, power, *etc*.). Therefore, it is important to select modes of exercise that will have the greatest transfer-of-training effect. Most track and field performances are multi-joint in nature and require the ability to quickly produce high levels of force.[45,46] Therefore, it is doubtful that single-joint exercises will have as much impact on performance as multi-joint training exercises.[43,47] In selecting training exercises and modes, a number of considerations and performance criteria can be used.[27,43,48] These criteria can maximize the transfer-of-training effect. Movement pattern characteristics include the following:[27,43,47,48]

1. The type of muscle action (e.g., concentric, eccentric, stretch shortening cycle (SSC)).
2. Accentuated areas of force production within the range of motion.
3. The complexity, amplitude, and direction of movement (includes open *vs.* closed kinetic chain, number of joints involved, large *vs.* small muscle mass).
4. Ballistic and semi-ballistics (e.g., weightlifting movements) *vs.* non-ballistic movements.

There must also be an overload application for continued successful performance adaptation. During early training (beginners), the task itself supplies sufficient overload for development. However, if overload is not continued, then sport performance will not improve beyond adaptation to simple practice of the sport. Factors to be overloaded can include force production, rate of force production, and power output. In choosing exercises for training explosive athletic performance, ballistic movements and “explosiveness” (rate of force development) are especially important.

4. The introduction of a monitoring process[27,49]

Monitoring program: the basic purpose of the monitoring/testing program is to assess an athlete’s current state of training, fatigue levels, and degree to which he or she has responded to the program. By integrating task- and sport-specific tests within the annual plan, factors associated with talent identification and assessment of performance can be understood.

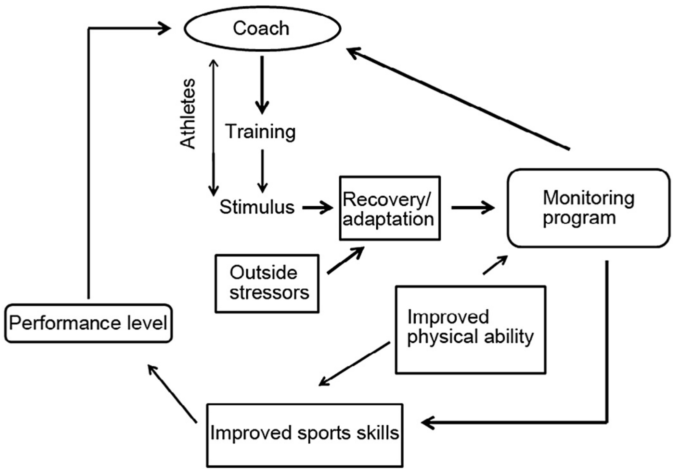

Fig. 1. The monitoring process.

Instituting an athlete-monitoring program into the annual plan is arguably the single most important aspect associated with assuring training program success. The monitoring tests should be integrated into the training process and be specific enough to answer basic questions concerning the athlete's level of fatigue, state of training, and whether or not the athlete is responding to the training stimulus as expected. Fig. 1 illustrates the basic concept of the monitoring program. Most importantly the monitoring program allows the coach to objectively assess why specific training programs work or do not work.

5. Summary

Planning a training program for strength/power athletes requires an understanding of both training principles and training theory. The training principles are overload, variation, and specificity. Each of these principles must be incorporated into an appropriate system of training. The concept of periodization embraces training principles and offers advantages in planning, allowing for logical integration and manipulation of training variables such as exercise selection, intensification, and volume factors. The adaptation and progress of the athlete is to a large extent directly related to the ability of the coach/athlete to create and carry out appropriate training plans. This ability includes:

1. An understating of how different types of exercises can affect strength and strength related variables (i.e., maximum force, rate of force development, power, *etc.*).
2. An understanding of the characteristics of exercises necessary for maximizing transfer-of-training effect such that training exercises have the greatest potential for carryover to performance. This understanding includes both movement pattern specificity and how to overload in a specific manner.
3. Implementing programs with variations at appropriate levels (macro, meso, and micro) such that performance progress is enhanced and the potential for overtraining is reduced.
4. Implementing programs that consider differences in trained state (i.e., novice *vs.* advanced and elite performers) and understanding that well-trained athletes may not always be well trained (i.e., summer and Christmas break).
5. Understanding that a maximum effort is necessary (even with light loads) to fully develop the neuromuscular system. For the coach/athlete, development of this ability is paramount and serves to advance sport performance.

References

1. DeWeese BH, Hornsby G, Stone M, Stone MH. The training process: planning for strength–power training in track and field. Part 1: theoretical aspects. *J Sport Health Sci* 2015;**4**:308–17.
2. Plisk S, Stone MH. Periodization strategies. *Strength Cond* 2003;**25**:19–37.
3. Harris GR, Stone MH, O'Bryant HS, Proulx CM, Johnson RL. Short term performance effects of high power, high force or combined weight training. *J Strength Cond Res* 2000;**14**:14–20.
4. Painter KB, Haff GG, Ramsey M, McBride J, Triplett T, Sands WA, et al. Strength gains: block *vs.* DUP weight-training among track and field athletes. *Int J Sports Physiol Perform* 2012;**7**:161–9.
5. Stone MH, Plisk SS, Stone ME, Schilling BK, O'Bryant HS, Pierce KC. Athletic performance development: volume load—1 set versus multiple sets, training velocity and training variation. *Strength Cond J* 1998;**20**: 22–31.
6. Matveev LP, Zdornyj AP. *Fundamentals of sports training*. Moscow: Progress Publishers; 1981.
7. Issurin VB. Block periodization *vs.* traditional training theory: a review. *J Sports Med Phys Fitness* 2008;**48**:65–75.
8. Viru A. *Adaptation in sports training*. Boca Raton, FL: CRC Press; 1995.
9. Zatsiorsky VM. *Science and practice of strength training*. Champaign, IL: Human Kinetics; 1995.
10. Stone MH, Fleck SJ, Triplett NT, Kraemer WJ. Health- and performance-related potential of resistance training. *Sports Med* 1991;**11**: 210–31.
11. Fry AC, Kraemer WJ, Stone MH, Koziris L, Thrush JT, Fleck SJ. Relationships between serum testosterone, cortisol and weightlifting performance. *J Strength Cond Res* 2000;**14**:338–43.
12. Stone MH, Fry AC. *Increased training volume in strength/power athletes. Overtraining in sport*. Champaign, IL: Human Kinetics; 1997.p.87–106.
13. Foster C. Monitoring training in athletes with reference to overtraining syndrome. *Med Sci Sports Exerc* 1998;**30**:1164–8.
14. Meeusen R, Duclos M, Foster C, Fry A, Gleeson M, Nieman D, et al. Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. *Med Sci Sports Exerc* 2013;**45**:186–205.
15. Vetter RE, Symonds ML. Correlations between injury, training intensity, and physical and mental exhaustion among college athletes. *J Strength Cond Res* 2010;**24**:587–96.
16. Ross A, Leveritt M. Long-term metabolic and skeletal muscle adaptations to short-sprint training: implications for sprint training and tapering. *Sports Med* 2001;**31**:1063–82.
17. Bruin G, Kuipers H, Keizer HA, Vander Vusse GJ. Adaptation and overtraining in horses subjected to increasing training loads. *J Appl Physiol* 1994;**76**:1908–13.
18. McGowan CM, Golland LC, Evans DL, Hodgson DR, Rose RJ. Effects of prolonged training, overtraining and detraining on skeletal muscle metabolites and enzymes. *Equine Vet J Suppl* 2002;**34**:257–63.
19. Stone MH, O'Bryant HS, Pierce KC, Johnson RL, Pierce K, Haff GG. Periodization: effects of manipulating volume and intensity. Part 1. *J Strength Cond Res* 1999;**21**:56–62.
20. Stone MH, O'Bryant HS, Pierce KC, Johnson RL, Pierce K, Haff GG. Periodization: effects of manipulating volume and intensity. Part 2. *J Strength Cond Res* 1999;**21**:54–60.

21. McBride JM, Triplett-McBride T, Davie A, Newton RU. The effect of heavy- *vs.* light-load jump squats on the development of strength, power, and speed. *J Strength Cond Res* 2002;**16**:75–82.
22. Padulo J, Mignogna P, Mignard S, Tonni F, D'Ottavio S. Effect of different pushing speeds on bench press. *Int J Sports Med* 2012;**33**:376–80.
23. Burleson Jr MA, O'Bryant HS, Stone MH, Collins MA, Triplett-McBride T. Effect of weight training exercise and treadmill exercise on post-exercise oxygen consumption. *Med Sci Sports Exerc* 1998;**30**:518–22.
24. Melby CL, Scholl C, Edwards G, Bullough R. Effect of acute resistance exercise on post-exercise energy expenditure and resting metabolic rate. *J Appl Physiol* 1993;**75**:1847–53.
25. McCaulley GO, McBride JM, Cormie P, Hudson MB, Nuzzo JL, Quindry JC, et al. Acute hormonal and neuromuscular responses to hypertrophy, strength and power type resistance exercise. *Eur J Appl Physiol* 2009;**105**: 695–704.
26. Thorton MK, Potteiger JA. Effects of resistance exercise bouts of different intensities but equal work on EPOC. *Med Sci Sports Exerc* 2002;**34**:715–22.
27. Stone MH, Sands WA, Stone ME. *Principles and practice of strength-power training*. Champaign, IL: Human Kinetics; 2007.
28. Minetti AE. On the mechanical power of joint extensions as affected by the change in muscle force (or cross-sectional area), ceteris paribus. *Eur J Appl Physiol* 2002;**86**:363–9.
29. Zamparo P, Minetti AE, di Prampero PE. Interplay among the changes of muscle strength, cross-sectional area and maximal explosive power: theory and facts. *Eur J Appl Physiol* 2002;**88**:193–202.
30. Tesch P, Larson L. Muscle hypertrophy in bodybuilders. *Eur J Appl Physiol* 1982;**49**:301–6.
31. Stone MH, Chandler TJ, Conley MS, Kramer JB, Stone ME. Training to muscular failure: is it necessary. *Strength Cond J* 1996;**18**:44–8.
32. Cormie P, McGuigan MR, Newton RU. Influence of strength on magnitude and mechanisms of adaptation to power training. *Med Sci Sports Exerc* 2010;**42**:1566–81.
33. Schoenfeld BJ. Is there a minimum intensity threshold for resistance training-induced hypertrophic adaptations? *Sports Med* 2013;**43**:1279–88.
34. Fry AC. The role of resistance exercise intensity on muscle fibre adaptations. *Sports Med* 2004;**34**:663–79.
35. Nuzzo JL, McBride JM, Dayne AM, Israetel MA, Dumke CL, Triplett NT, et al. Testing of the maximal dynamic output hypothesis in trained and untrained subjects. *J Strength Cond Res* 2010;**24**:1269–76.
36. Hakkinen K. Neuromuscular adaptation during strength training, aging, detraining and immobilization. *Crit Rev PhysRehabil* 1994;**6**:161–98.
37. McBride JM, Triplett-McBride T, Davie A, Newton RU. A comparison of strength and power characteristics between power lifters, Olympic lifters and sprinters. *J Strength Cond Res* 1999;**13**:58–66.
38. Cormie P, McGuigan MR, Newton RU. Adaptations in athletic performance after ballistic power versus strength training. *Med Sci Sports Exerc* 2010;**42**:1582–98.
39. Cormie P, McGuigan MR, Newton RU. Changes in the eccentric phase contribute to improved stretch-shorten cycle performance after training. *Med Sci Sports Exerc* 2010;**42**:1731–44.
40. Behm DG. Neuromuscular implications and applications of resistance training. *J Strength Cond Res* 1995;**9**:264–74.
41. McDonagh MJN, Hayward CM, Davies CTM. Isometric training in human elbow flexor muscles. *J Bone Joint Surg Br* 1983;**64**:355–8.
42. Wilson GJ, Newton RU, Murphy AJ, Humphries BJ. The optimal training load for the development of dynamic athletic performance. *Med Sci Sports Exerc* 1993;**25**:1279–86.
43. Stone M, Plisk S, Collins D. Training principles: evaluation of modes and methods of resistance training—a coaching perspective. *Sports Biomech* 2002;**1**:79–103.
44. Stone MH, O'Bryant HS, McCoy L, Coglianese R, Lehmkuhl M, Schilling B. Power and maximum strength relationships during performance of dynamic and static weighted jumps. *J Strength Cond Res* 2003;**17**:140–7.
45. Weyang PG, Sternlight DB, Belizzi MJ, Wright S. Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *J Appl Physiol* 2000;**89**:1991–9.
46. Clark KP, Weyand PG. Are running speeds maximized with simple-spring stance mechanics? *J Appl Physiol* 2014;**117**:604–15.
47. Zajac FE, Gordon ME. Determining muscle's force and action in multi-articular movement. *Exerc Sport Sci Rev* 1989;**17**:187–230.
48. Siff M. Biomechanical foundations of strength and power training. In: Zatsiorsky V, editor. *Biomechanics in sport*. London: Blackwell; 2001.p.103–39.
49. DeWeese B, Gray HS, Sams ML, Scruggs SK, Serrano AJ. Revising the definition of periodization: merging historical principles with modern concern. *Olym Coach Mag* 2013;**24**:5–19.